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REPORT

OF THE

STATE GEOLOGIST

ON THE

Mineral Industries and Geology

of Certain Areas

OF

VERMONT.

1905-1906.

FIFTH OF THIS SERIES.

GEORGE H. PERKINS, Ph. D.

State Geologist and Professor of Geology, University of Vermont

MONTPELIER, VT.
ARGUS AND PATRIOT PRESS.
1906.

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STATE OF VERMONT.

OFFICE OF STATE GEOLOGIST.

BURLINGTON, VT., *October* 1st, 1906.

To His Excellency, C. J. Bell, Governor of Vermont:

SIR:—In accordance with the provisions of Act 6, 1900, I herewith respectfully present my Fifth Biennial report as State Geologist. The following pages furnish a summary of work carried on during the years 1905 and 1906.

Through the generosity of the authors of the papers included in this Report a far more valuable collection of material has been obtained than would otherwise have been possible with so limited an appropriation as that which has been available for this work.

As has been true heretofore, much of the investigation which has been carried forward has been accomplished with little more expense to the State than the actual outlay for travelling and necessary incidentals.

The usual large number of ores and other minerals has been examined and reports sent out from this office as to their commercial value. Many deposits of supposed valuable rocks and minerals have been visited, and the owners advised respecting their treatment and an extensive correspondence carried on.

The introduction which immediately follows gives further information as to the work of the two years.

Respectfully submitted,

G. H. PERKINS.

INTRODUCTION.

The following pages form the Fifth Report of the present State Geologist. Besides giving the results of new investigations this Report carries forward some of those which have found place in previous volumes.

In the Report immediately preceding this, issued in 1904, the following topics were considered, namely: A Sketch of the Life and Work of C. B. Adams, a Bibliography of the Geology of Vermont, A Report of the progress in the Mineral Industries of the State during the two years, Papers on The Glaciation of the Green Mountains, The Serpentine Belt of Lamoille and Orleans Counties, The Geology of Grand Isle County, The Stromatoceria of Isle La Motte, The Lignite Deposit of Brandon, and its Associated Clays, Description of many new fossils from the Lignite, and a brief account of the Hydrology of Vermont.

It has long been the plan of the Geologist to investigate the geology of the State not so much in a general way as a whole, as in more detailed and therefore thorough fashion, taking up one after another small areas, a few each year, until the entire surface of the State is covered.

Necessarily, it will be some years before the end of this task can be reached, indeed the complete and satisfactory conclusion of such work is never reached, there always remain problems unsolved and perhaps insoluble, and yet by patient continuance in well doing the Geologist hopes to see at least a fair beginning accomplished. Already, Grand Isle County is for the present finished so far as the more general outlines of the region are concerned, though there remains very much paleontological work to be done. This investigation is carried into Franklin County in this Report and it is my hope that the geology of this and Chittenden County, work in which has also been begun, may be more fully presented in the following Report.

It is a part of the plan to carry the work of investigation first through those counties which border the eastern shore of Lake

Champlain and work from this, the western side of the State, toward the interior. At the same time quite extensive investigation of the northern portion of that part of the State which lies east of the Green Mountains has been carried forward for the last four years. Here wholly different conditions are found in the rocks and new problems present themselves. Mr. G. E. Edson has been working as field Assistant in Franklin County and Doctor C. H. Richardson of Syracuse University in the eastern part of Vermont. Papers by these gentlemen are among those that follow. The difficult problems which are found in the study of the asbestos region about Belvidere Mountain were considered in the previous Report and much time and study has been given to them by Professor V. F. Marsters who planned to spend some time in the region this season for further investigation the results of which were to have formed a part of this Report. An unexpected call to Peru as Government Geologist, however, put an end to this work. Nevertheless, it has been possible to supplement the former discussion of this subject by reproducing parts of a paper recently published by Professor Marsters in BULLETIN GEOL. SOC. AMERICA, VOL. 16, and through the courtesy of the Society and its Secretary, I am able to give some of the plates by which the paper is illustrated.

These two papers give as thoroughly worked up an account of the geological and mineralogical characters of this limited region as has been furnished for any part of the State.

As Dr. Richardson's paper shows, he has carefully gone over and studied the rocks of Essex, Caledonia, Orleans and parts of Lamoille and Washington counties. Mr. Edson has very thoroughly gone over that part of Franklin County in and adjacent to St. Albans and besides the results of recent exploration he has presented those which have come from several years of diligent collecting in this region so well known to students of Cambrian rocks.

Professor H. M. Seely, who for many years has been interested in the study of the lower forms of life in Ordovician terranes, has several papers in this Report in which he gives much new and interesting material concerning some of these very puzzling forms.

The study of the Brandon Lignite and its contained fossils which was commenced by the Geologist several years ago and many results of which were given in the last Report, has been continued and new results will be presented in following pages. The Geologist is most glad to be able in this connection to give a very valuable account of the microscopic structure of the Lignite by Doctor E. C. Jeffrey of Harvard. Probably no one is better qualified to speak as an authority upon this subject than Doctor Jeffrey and therefore his conclusions are of importance.

Professor C. H. Hitchcock, of Dartmouth, who was one of the staff of the old Geological Survey of the State which reported finally in 1861, has for the past two years returned to field work in this State, chiefly in the study of the surface geology of a small area and has furnished the papers which will be found on subsequent pages.

The last portion of the volume contains as full an account of the supplies from which the drinking water of the different towns of the State is taken as it has been possible for the Geologist to compile from the data obtainable. Preceding the above mentioned papers will be found an account of the Mineral Industries of the State. It will there be seen that most of these have been exceedingly prosperous and increasingly so during the two years covered by the Report.

In conclusion I wish to state that the papers mentioned above have been printed very much as they were left by their authors and that I have not attempted to modify or alter any views therein expressed and it is to be distinctly understood that each author is alone responsible for whatever views he may have seen fit to present.

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MINERAL RESOURCES.

The importance of the mines and quarries of Vermont as stated in the Report of 1903-1904 has become still greater during the past two years. As everywhere in such industries, changes of more or less importance have taken place, independent companies have consolidated, new ones formed, new enterprises undertaken, and new methods adopted, and for the most part the business of these companies has been steadily increasing. Some quarries have been closed, temporarily or permanently, some companies report smaller sales than previously, but by far the larger number report advance in methods, increased production and larger sales. Therefore on the whole, the steady and quite substantial increase in the sales of our different varieties of stone noticed in former Reports, continues and the outlook is very promising for yet larger developments in all directions. Indeed during the last two years the increase in the stone industry has been greater than ever before.

As it has been necessary to state in former reports, it is not and never has been, possible to give a wholly full and accurate report of the amount of capital, number of men and value of sales of our quarries for the reason that it has been impossible to get definite statements from a considerable number of firms as to these matters. The most ample opportunity has been given to all stone working firms in the State to supply such information as should give Vermont her proper place as a stone producer. At least this is what the Geologist has attempted, but, while by far the greater number of companies, including most of the larger ones, have very fully replied to the circulars of inquiry sent out, a respectable minority have paid no attention to them. For this reason the totals given are to be considered as to some extent incomplete and below the real facts.

So far as I have been able to ascertain, the total capital invested in mines, quarries and mills for working stone in Vermont is $12,348,410. 10,426 men are employed and of course, there are many others dependent upon these. The sales of stone for the last year, 1905, were $9,614,000.

The three great stone industries of Vermont, as everyone well knows, are Granite, Slate and Marble and in the production of these this State stands in the foremost rank. This place the State has long held, and in spite of the greatly increased production in other states, Vermont may without exaggeration be said to lead the world in the production of the more costly and desirable kinds of ornamental and building stone. The marbles, granites and slates of Vermont are well and most favorably known in all civilized countries and at one time or another within the past few years have been sent to them all.

Besides marble, granite and slate, Vermont quarries and sells in less quantity limestone, talc, soapstone, kaolin, fire clay, ochre, sandstone and copper (chalcopyrite).

As must always be true, the wealth of Vermont is in the quarries while the mines are comparatively unimportant and the increase mentioned has been in the production of all kinds of stone, but, as will be shown later, especially in granite.

What this increase has been and what the real importance of the quarries is may be seen by looking over the following statistics which are taken from the Reports of the United States Geological Survey.

The total sales of stone of all kinds in Vermont are given as follows:

1880	$1,752,333.
1900	$4,704,202.
1901	$5,366,740.
1902	$5,889,208.
1903	$6,605,060.
1904	$8,055,133.
1905	$9,614,000.

The figures for the last year are taken from the reports which I have received from the different quarries and cutting works.

From the above it will be seen that, while during the ten years from 1880 to 1890 the increase was about $3,000,000, that for the last three years, 1903, 1904 and 1905 has been as great, showing that large as former sales have been, those for these years have increased about three times as rapidly as during the earlier years. Nor can there be any doubt that the present year, 1906, will show at its close a still greater increase.

BUILDING AND ORNAMENTAL STONES.

MARBLE.

In the marble business, as in other industries, the tendency has been towards consolidation. No great trusts have been formed, but several of the smaller firms have been bought out by those that had greater resources.

At present nearly all of the marble business, at least so far as quarrying is concerned, is carried on by ten companies. These are the following: in alphabetical order.

The Brandon-Italian Marble Company. This company has a large quarry at Brandon and extensive mills at Middlebury, where the water power furnished by Otter Creek is utilized.

The Brandon marble is much like some of that from the quarries south near Rutland, that is, it is a good, sound, durable stone, white or more or less veined or clouded.

The Bennington Marble Company. This is a new company and is not yet fairly under way. The office is in Dorset.

The Columbian Marble Company. The quarry of this company is at Proctor and they have a large and well equipped mill at Rutland. The stone produced is of the same sort as that usually sold under the name, "Rutland Marble" which varies from pure white statuary to dark, clouded stone.

The Eastman Marble Company has a small quarry at West Rutland, but no mill, the stock as quarried being sold to other companies for working.

J. K. Freedlys Sons have a quarry high up on the eastern side of Dorset mountain. This is one of the oldest of our quarries and produces a variety of hard, crystalline and excellent stone. From the quarries there is an inclined tramway by which stone is sent down to the mill beside the track of the Rutland & Bennington R. R., at East Dorset.

The Norcross-West Marble Company have quarries at Dorset, two of which were figured in the last Report, other quarries recently opened in Danby are being actively worked and there is a large and finely equipped mill at Manchester. This is connected with the Dorset quarries by a railroad six miles long which is owned by the company.

This company make a specialty of building marble and have supplied the stone for some of the finest public buildings in the country, notably the New York Public Library in course of construction.

The Raleigh Marble Company work a quarry at Fowler. The office is in Rutland. The marble handled is what is called "Blue" a compact, dark and fine stone.

Rutland-Florence Marble Company. The headquarters of this company are at Fowler, a place which has been really created by the business of the company. They are now working eight quarries, and are doing a large and rapidly increasing business. Their mill at Fowler is in some respeots the finest and most modern that I have seen, though others approach it very closely. Some of the quarries are in Pittsford.

The Sterling Marble Company. This company has a mill in Middlebury and quarries in Pittsford. I am informed by one interested in the business that a new company, The Middlebury Marble Company, has recently been formed and that this company has been consolidated with it.

The Middlebury Marble Company own quarries in northeast Middlebury and propose to erect a mill at Beldens the coming season.

The Vermont Marble Company. Some of the companies just named are large and do a large business, but probably there is no company in the world which quarries, works and sells anything like the amount of marble that is handled by this company. Their business, moreover, is reported as increasing. The company have mills at Proctor, where are the principal offices and general headquarters, West Rutland, Center Rutland, Brandon, East Dorset, Beldens, and Swanton. The numerous quarries are at Proctor, West Rutland, Pittsford, Danby, Swanton and Roxbury. Within the past few years the Vermont Marble Company has bought and is now working the plants formerly worked by the Barney Marble Company at Swanton, the John Cullen Quarry, Imperial Quarry, and Danby Marble Company's Quarry at Danby, and the mill and quarries formerly belonging to the G. E. Royce estate. A large variety of marble is obtained from these different quarries.

All of the marble which is quarried in Rutland County, and most of the marble sold in the State comes from this region, is light or white except a relatively small quantity of the dark clouded varieties, but from the Swanton quarries a wholly different stone is taken. This is a hard siliceous limestone, or rather calcareous sandstone, which has not been in any way metamorphosed, as have all of the Rutland marbles. The colors of the Swanton marbles are shades of red and white mottled in infinite variety. The stone is much harder and for this reason more costly than the common marbles and takes a more brilliant polish. But still harder and more elegant is the "Verde Antique" which is a serpentine quarried at Roxbury. I have called attention to this stone in previous Reports. It seems to me the most beautiful stone for interior finish that is quarried anywhere, and it is pleasant to know that, notwithstanding its necessarily high price, the demand for it is largely increasing.

Quite a number of old and abandoned quarries have been reopened of late and are now being worked. This is mainly due to the increased demand for marble in building. It is easily seen that while a block or slab of stone must be perfect throughout if it is to be used for a monument where all parts are exposed, it is quite possible that a piece may be more or less discolored or otherwise imperfect on one side and yet, if the opposite is perfect, it can be properly placed in a building where only one side is left exposed. Thus marble that is of no value for monumental work may be just as good as any other for structural work. For the same reason a stone that is not very strong may be useful for interior work, where not only all but one surface is covered, but where it is to be simply ornamental and not only does not support any part of the building, but may itself be supported. For these reasons marble which a few years ago could not be sold because such stone was little called for except for monumental work can now find ready market.

The total capital invested in the marble companies of Vermont is $7,990,000. Number of men employed 4,100. Value of marble sold in 1905, $3,610,000.

The above should be increased by the statistics of the numerous small concerns which buy and cut marble in many of the towns of the State. The largest of these companies who work no quarries, but cut the stone is Temple Brothers of Rutland. This firm do an extensive business.

For many years the geological age of the marbles of Rutland county was in doubt. But finally through the investigations of Rev. A. Wing, as shown in the Biography of Mr. Wing by Professor Seely in the Third Report, the truth began to be made apparent and since then Mr. Wing's conclusions have been abundantly verified. Within recent years slabs sawed from blocks taken from the bottom of the old Ripley quarry have shown, very distinctly, sections of *Maclurea magna* and, less easily determined, other fossils which fix the age of these marbles at least, as Chazy. The stone is undoubtedly marble and yet it is not so completely changed that all fossils have been obliterated.

So far as I have seen all the *Maclureas* are distorted, but they are very distinct.

The geology of the Swanton marbles was discussed in the First Report. They are simply calcareous members of the Cambrian Red Sandrock. In some of the sawed slabs numerous specimens of *Salterella pulchella* may be seen.

LIMESTONE.

Limestone is used both as a building stone and for making lime. Stone suitable for the latter purpose is not widely distributed over the State, but there are a number of very good deposits.

In Colchester, Mr. G. B. Catlin has a lime kiln with several furnaces. At Highgate, Mr. L. E. Felton, at Swanton, Mr. J. P. Rich, and at St. Albans, Mr. W. B. Fonda, have large works where lime is manufactured on a large scale. At Leicester Junction the Brandon Lime and Marble Company and the Leicester Marble-Lime Company are in active operation. The lime is shipped in barrels, sacks and in bulk.

Some lime is made in several other localities, but I have not been able to get details from them.

Aside from local quarrying, for underpinning and walls, limestone is quarried in several places and sold for building and road material. The only large quarries, so far as I know, are those of Mr. N. W. Fisk and Mr. E. S. Fleury on the south end of Isle La Motte.

SLATE.

Like the other stone industries the slate business has been unusually active during the past two years and in some departments it is now said that the demand exceeds the supply. Some of the foreign markets have fallen off, as that in South Africa, but others have been found that more than take their place.

While the total sales of slate in Pennsylvania greatly exceed those of Vermont, it is said that for those uses which require large slabs such as are needed for billiard table tops, tanks and the like the Vermont slate is more in demand.

Certain colors, as unfading green and purple which are abundant in Vermont are found nowhere else. Thus in the production and sale of certain kinds of slate, this State has a monopoly.

Most of the slate sold in Vermont is obtained in Rutland county.

The geology of this region and a general account of the slate was given in the Second Report and a more complete discussion of this subject is given in an article by Professor T. N. Dale in the 19th Annual Report of the U. S. Geological Survey, pp. 153-387.

More recently, in a Bulletin, No. 275 of the U. S. G. S., Prof.

PLATE I.

Typical Slate Quarry, Pawlet, Vt.

Dale has given us a fuller discussion of all the "Slate Deposits and Slate Industry of the United States."

Those especially interested in Slate will find this last named work exceedingly useful for reference as it contains in compact form a great deal of information concerning the subject treated. The following extract from the account of Vermont slate is of general interest. "There are at least four distinct slate districts in Vermont. The most easterly extends along the Connecticut River for more than two thirds the length of the State. The slate is black or dark gray, and has been worked in Guilford, in Windham County at the extreme southern end of the State, and also in Thetford, in Orange County, and at Waterford in Caledonia County.

The next extends along the eastern flank of the Green Mountain range from the Canada line to about the middle of the State and has been extensively worked in Northfield, in Washington County. The most important district, which furnishes the well known green and purple slates lies between the Taconic range and Lake Champlain, extending from Sudbury in Rutland County, southward to Rupert, in Bennington County, a distance of 26 miles. This belt also passes southwest into Washington County, N. Y., where, however, it has proved of far less economic importance.

The fourth is a black slate, as yet undeveloped, and covering from, 10-12 square miles in the town of Benson, near Lake Champlain."

As stated in the above publications, the slate of Rutland County is of different colors, green, purple, variegated, gray, and these may be found in several varieties. One quarry may produce only one sort, another may produce several. The kind known in trade as "Unfading Green" is usually harder and more compact than the other sorts, but this is not always the case and in different quarries, the same sort of slate, apparently, may be quite different in hardness.

The quarries located in the southern part of the State belt usually produce a slate that can be readily split into roofing material and many quarries produce only roofing slate, others produce this and the more compact, less easily split stone which is known as mill stock. Others, especially those in the northern part of the region, produce only mill stock. A half dozen or more different beds of slate have been found in a single quarry though this is not common. So far as I have been able to ascertain the following companies are at present engaged in the slate business in this State.

LIST OF COMPANIES PRODUCING SLATE IN VERMONT.

American Sea Green Slate Company, Granville, N. Y.
Auld & Conger, Poultney.
Allen & Son, Fair Haven.
Bonville Brothers, Fair Haven.
Clayton & Burdick, West Pawlet.
Durick & Flannagan, Fair Haven.
Durick & Keenan, Fáir Haven.
Eastern Slate Company, Poultney.
Eureka Slate Company, North Poultney.
Edwards Slate Company, Poultney and Wells.
Fair Haven Marbleized Slate Company, Fair Haven.
Fleming Slate Company, Poultney.
Green Mountain Slate Company, Poultney.
Griffith & Nathanael, Poultney.
Griffith, Thos. R., West Pawlet.
Hinchey Brothers, Hydeville.
Hughes, W. H. Slate Company, West Pawlet.
Hughes—Snyder Slate Company, Poultney.
Johnson & McCormick, Pawlet.
Jones, Roberts & Rowland, Poultney.
John J. Jones Slate Company, Castleton.
Jones & Owens, Fair Haven.
Maley Brothers, Fair Haven.
Matthews Slate Company, Poultney.
Minogue Jas., Castleton.
Morris Chas. Slate Company, Poultney.
Nelson Brothers & Morof, West Pawlet.
Northfield Slate Company, Northfield.
Norton Brothers, Granville, N. Y.
New York Consolidated Slate Company, Poultney.
O'Brien Brothers, Wells.
Parry, Jones & Owens, Poultney.
Penryn Slate Company, Hydeville.

PLATE II.

Slate Quarry.

LIBRA[illegible]
O[illegible]
UNIVER[illegible]
[illegible]ALIFORNI[illegible]

Peerless Slate Quarry, Fair Haven.
Rice Brothers, South Poultney.
Rising & Nelson, West Pawlet.
Roberts, G. T., West Pawlet.
Rutland County Slate Company, Poultney.
Sheldon, F. C., Granville, N. Y.
Union Slate Company, Hydeville.
*Valley Slate Company, Fair Haven.
Vermont Black Slate Company, Northfield.
Vermont Marbleized Slate Company, Fair Haven.
Vermont Slate Company, Granville, N. Y.
Vermont Unfading Green Slate Company, Fair Haven.

I am indebted to Mr. Wm. Griffith of Poultney for aid in compiling the above list.

In Northfield and Benson there are deposits of black slate. Those at the former place are extensive and well located and at different times they have been worked to a considerable extent.

At present two of the Northfield quarries are worked.

The Northfield Slate Company is working the Union Quarry for roofing slate and the Vermont Black Slate Company is working a quarry about two miles south of the village and have a fine showing of slate exposed. I have never seen so large slabs of slate taken from any quarry as could be taken from one face in this quarry. The jointing is such that the slaty cleavage is nearly perpendicular and from the face in question a clear slab forty by fifty feet could be taken. A new departure in this region is being taken by this company.

Instead of confining their work to roofing slate, as has been done at all of the Northfield quarries, a mill, equipped with ample machinery is now well installed, and some of the machinery is working. The stone is said to be very good for milled stock and the use of the Northfield slate for the numerous purposes for which the milled stock is sold must add materially to its market value.

In the Bulletin above mentioned Professor Dale says of the Northfield slate:"

"*Geological relations.*—The Vermont geological map[a] repre-

*This Quarry has recently been purchased by The Montauk Slate Company.
[a] Hitchcock and Hager Rept. Geol., Vermont, vol. 2, 1861. Pl. I, p. 794.

sents a belt of clay slate, from 1 to 7 miles wide, as extending from Lake Memphremagog along the east side of the Green Mountain axis as far south as Barnard in Windsor County, a distance of 90 miles. A recent paper and map by Richardson[b] represents a portion of this slate belt 52 miles long, extending from North Calais, in Washington County, to a point in Windsor County nearly 10 miles west of White River Junction. The age of this slate formation was thought to be probably Devonian by the authors of the older report,[c] but Richardson regards it as Lower Trenton. Conclusive paleontological evidence on the subject is yet lacking.

This slate has been quarried at Montpelier and Northfield, which are 10 miles apart. The strike of bedding at both places ranges from N. 10° to 20° E. At the Vermont Black Slate Company's quarry, 2 miles south of Northfield, the beds occur in minor very acute folds, which strike N. 10° E., while the cleavage, with an almost identical strike, dips W. at 75°. This indicates that the general course of the bedding is not far from horizontal and that lateral repetitions of strata are to be looked for. The interpretation given by Richardson of Pl. XV in his paper, referred to above, requires corroborative microscopic evidence. The low easterly (by error printed west) dipping planes resemble a secondary cleavage, while the steep westerly ones have the characteristics of bedding.

The slate continues about 300 feet west of this quarry, and about a third of a mile east, making its total width in that vicinity about 2,000 feet. The general relations of this slate on the west are these: The western part contains a bed of novaculite up to 12 feet thick, and is followed by slate of no commercial value, which is followed at the foot of the range, about three-fourths miles southwest of the village, by a sericite-chlorite-quartz-schist with grains of plagioclase, with a vertical slip cleavage striking about north and a plicated bedding with a

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[b] Richardson, C. H., The Terranes of Orange County, Vt., Slate, p. 77-79, and map, Pls. IX, IXA, in Rept. State Geologist Vermont, (3) of New Series, 1901, 1902.

[c] vol. 1, p. 497.

thin-bedded, more or less muscovitic quartizite (with grains of zircon and plagioclase), so intricately folded as to strike N. 20° range 2 miles west of the village, there is a large exposure of northerly pitch. After a covered interval, at a point on the E., N. 20° W., N. 50° E., and N. 90° E. An area of a few acres of muscovite granite (formerly quarried, Moses King property) lies within this quartzite, or at least with this quartzite on both its east and west sides. This granite in places becomes orbicular, carrying nodules of concentrically arranged mica an inch in diameter.

Northfield Slate.—In 1904 but one quarry was in operation at Northfield, that of the Vermont Black Slate Company, which measures about 100 feet along the strike, 60 feet across it, and 55 feet in depth. The relations of cleavage and bedding are shown in fig. 11. The cleavage strikes N. 12° E. and dips 75° W. Strike joints strike N. 15° E., dip 50° W., dip joints N. 77° W., and dip 85° S. Diagonal joints strike N. 55° E. and dip 65° NW. The grain dips 70° N. An exceptional false cleavage dips 15°-20° N. As there are no ribbons in the bedding nor horizontal joints crossing the cleavage, channeling in a horizontal direction becomes necessary. It is, therefore, easier to obtain very large slabs for mill stock than small ones for roofing slates.

The slate is very dark gray ; to the unaided eye has a very fine texture. The cleavage surface is very smooth and very lustrous, but has here and there minute longish crystals of pyrite pointing in the direction of the grain, also some very minute nonmetalic lenses. It appears to be slightly graphitic and contains a very little magnetite. The sawn edge shows lenses and crystals of pyrite from 1 to 3 mm. long. There is no effervescence in cold dilute hydrochloric acid. It is very sonorous, very fissile, and does not discolor.

Under the microscope shows a matrix of muscovite (sericite), with a very brilliant aggregate polarization and a very even texture. There are abundant quartz fragments up to 0.06 mm., exceptionally 0.1 by 0.03 mm. The lenses and crystals of pyrite (including a small percentage of magnetite) number from 7 to 8 per square millimeter and measure from 0.05 by 0.03 up to 0.06 by 0.1 mm. These figures, however, do not include the exceptionally large ones, visible without a glass. The long axes of these lenses and crystals lie in the cleavage but parallel to the grain. They are usually surrounded by a rim of secondary quartz and muscovite, sometimes also of chlorite, radiating from the nucleus a distance of 0.04 to 0.08 mm. In some cases these secondary minerals radiate only in the zone of the cleavage of the slate. There are a few lenses of interleaved muscovite and chlorite. Considerable dark gray, probably graphitic, matter in extremely fine particles, very little carbonate, prisms of rutile up to 0.04 by 0.006 mm. and more rarely irregular angular masses of the same mineral, and finally some crystals of tourmaline, 0.36 by 0.008 mm. The nonmetallic lenses referred to above are evidently the quartz-coated pyrite lenses.

The chief constituents of this slate, arranged in descending order of abundance, appear to be muscovite (sericite), quartz, pyrite, graphite, magnetite, chlorite, carbonate, besides accessory rutile and tourmaline.

For the reason given the product of this quarry is destined almost entirely for mill stock, but the examination shows it to be a superior roofing slate.

The following data were gathered at the abandoned quarry of the Union Slate Company a half mile east-southeast of Northfield: Bedding strike, N. 10° E., dip 80° W; cleavage strike, N. 4° E., dip 70° W. Strike joints dip, undulating, low west; diagonal ones strike N. 60°-65° W. and dip 75° NE."

In previous Reports, there have been given brief accounts of the methods employed in quarrying and manufacturing marble and granite. It is hoped that similar facts concerning the getting and manufacture of slate will not be uninteresting.

The most conspicuous feature that is seen as one approaches a slate quarry is the dump or waste heap. There is, I judge, a larger amount of waste, relatively at least, in a slate quarry than in those of other sorts of stone. The quarry itself is not usually seen until it is approached closely, for it is generally a deep pit, a more or less quadrangular opening which ever

PLATE III.

Slate Quarry Showing Carriers in use.

grows deeper as the slate beds are followed down until it may be three hundred feet down or occasionally, somewhat deeper. For this reason, it is not possible to get a good picture of a slate quarry. Illustrations of various quarries have been given in previous Reports, and plates I and II show two others.

The quarry would be worked at great disadvantage had not the "Carriers" of which there are several kinds been invented. On Plate III several of these are shown in position as they are used in the quarry, and Plate IV shows the carrier more plainly.

Several sorts of carriers are in use and usually there is more than one kind in a quarry. The principal feature in all of them is the automatic action by which a vertical motion can be changed to a horizontal one at once and at any point. By an arrangement of wheels, levers and stops in these carriers the block of slate is raised from the pit up to the desired point, and then the whole apparatus, carrier and piece of slate, is carried along an inclined wire cable to a point near a shed or mill when the horizontal motion is stopped and the slate is let down to the ground or onto a waiting car. Instead of a block of slate, a large tray or pan made of iron and several feet square and a foot or so high is used to carry off the waste. This works on the same plan as that just described, but differs in some respects. The pan is so arranged that when over the waste heap it automatically turns and drops its load after being let down to a greater or less distance and then returns to its original position where it receives another load.

Derricks of the ordinary sort are used to some extent in the slate quarries, but the carriers largely take their place, and it is this more than anything else which causes a group of slate quarries to appear unlike other similar regions.

A block of greater or less dimensions having been taken from the quarry, if it is suitable for splitting into roofing slate is prepared for market by very few and simple processes.

It is simply landed near a shed and first split carefully, a wooden mallet being used, until it is broken into a few blocks of such size that each can be readily trimmed to the dimensions of one of the several sizes demanded by the market for roofing. Sometimes holes are drilled in the large blocks and wedges carefully driven into these and the breaking thus effected. The blocks having been brought to desired size are taken one by one, the edge thoroughly wetted and then split by hand, into an astonishingly large number of pieces, a broad thin chisel and mallet being used. A piece two inches thick may be split into as many as thirty pieces suitable for roofing and experts sometimes show their skill by splitting out much thinner slabs. The process seems very simple, but it really requires much skill and steadiness. This is shown by the fact that some of the best workmen cannot split as successfully if one is watching them as if alone.

Of course, the edges of the split pieces have all of the irregularity of the block from which they came. They must be trimmed. Plate V shows a common form of the "Trimmer"*. By a sharp, quick blow of the revolving knife the irregular piece is rapidly squared into the largest standard size which can be made from it.

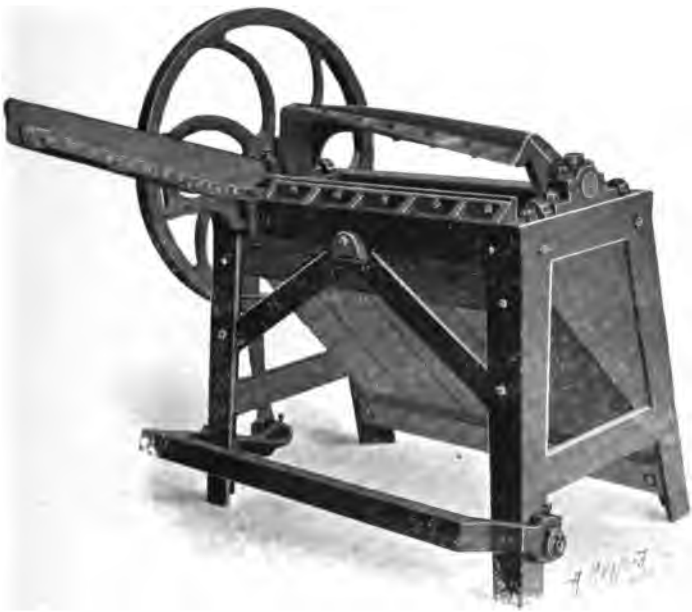
As the thin and apparently brittle slab of stone is placed under the trimming knife it would seem impossible that it should remain whole. Every blow seems calculated to break it into fragments, but this rarely happens. On the contrary, the blow of the knife, which is not unlike that of a lawn mower, cuts the slab squarely and well.

One curious fact is stated by all the slate men. If slate freezes hard and is then thawed it will not split, but is "dead." If taken while frozen, it can then be split about as well as if not frozen. Experiments have shown that freezing and subsequent thawing change the structure of a block of slate.

During some severe winters a considerable amount of good stock is injured by the freezing and thawing, so that slate quarry owners do not like to work out more than can be taken care of within a short time if the temperature is very low.

* For illustrations of this and other Slate working machinery I am indebted to the Ruggles Machine Company of Poultney.

PLATE V.



Slate Trimmer.

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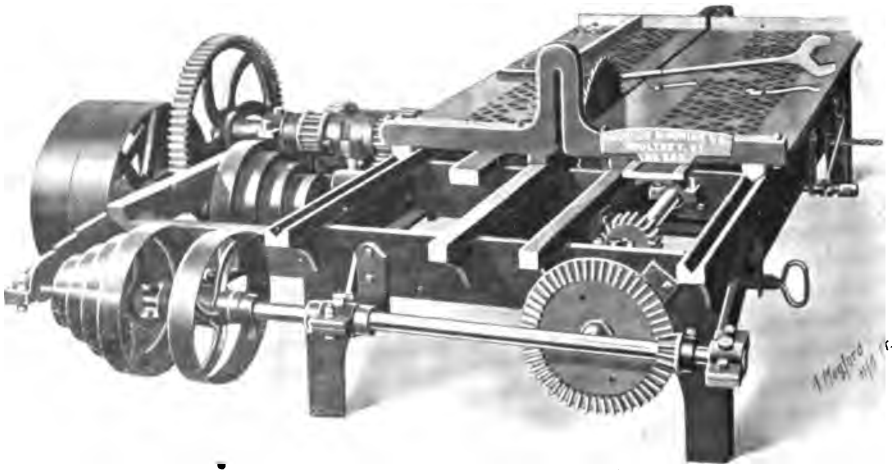
PLATE VI.



Slate Sawing Machine,

As has been noticed, if slate is to be used for roofing, only moderate sized blocks are taken out, but if the stone is to go to the mill the block may properly be much larger. In some quarries very large pieces are not often obtained readily, but in others pieces as large as any of the machines by which it is to be worked can receive may easily be gotten out. I have seen slabs three or four or even six inches thick and twenty feet long by six feet wide, at several of the mills. Usually, however, pieces of less dimensions are taken, since these are large enough for all the purposes of trade and more easily handled.

The large block having been freed from its original bed and split at the quarry into slabs a few inches in thickness, is deposited at some mill. Here the first process through which it usually passes is that of sawing. The saw, Plate VI, is in most cases a circular one with large, thick teeth.

As the figure shows, the bed of the sawing machine on which the stone rests is somewhat peculiar. Besides the various guides to enable the workman to saw out a perfectly rectangular piece, the table on which the stone rests is made in open work so that there are numerous places into which the workman can thrust a bar when he wishes to move the piece which is being sawn.

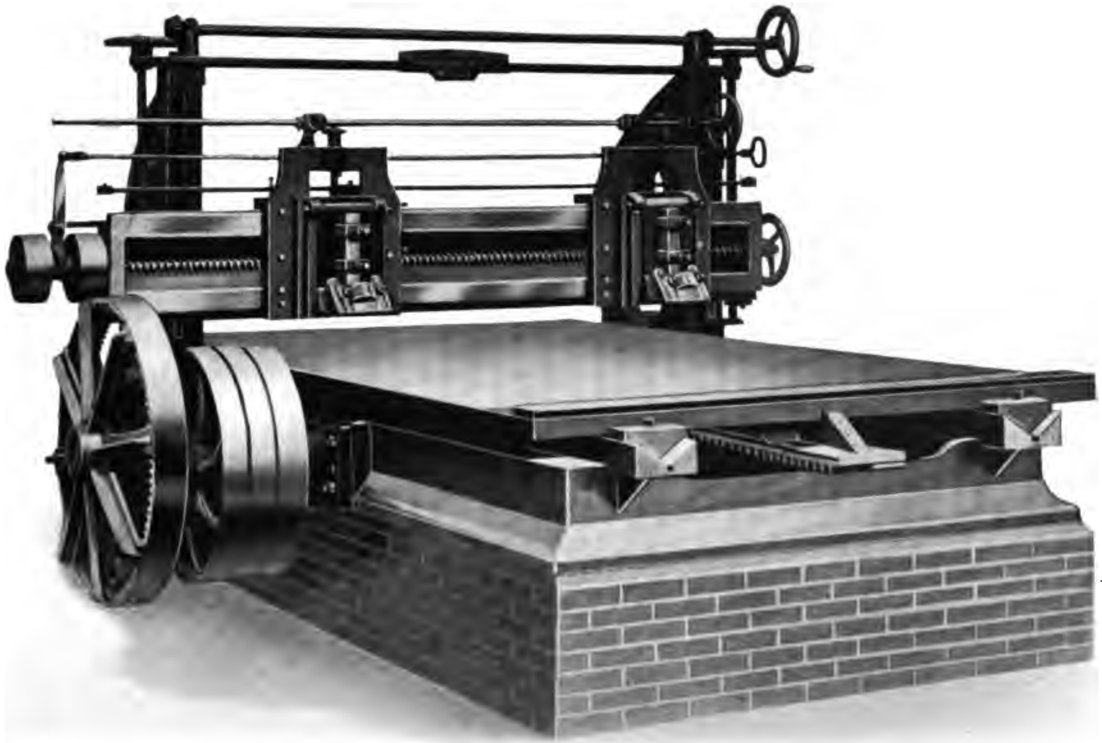
Skill in handling, of course, is an important factor, but this and other features in the construction of the table make it possible for a man to move a very large slab of stone single handed. These saws are arranged with three different speeds of feed and by arrangements of pulleys a number of additional speeds may be had. This is necessary because of the varying quality of the slate. Some of it is much harder and this must be cut more slowly, than other sorts. The thickness of the block or slab also must be taken into account. But even when the slate is of the hardest, the saws are able to cut through it with unexpected rapidity. What would be considered the average time necessary for sawing average slate of a given thickness I was not able to learn. The men in the mills said that it varied so much that they could give no definite statement. I watched several pieces as the saw went through them. One piece of unfading green which was four feet and six inches long and three inches thick was sawed from end to end in two minutes and a half. The rate at this time was not far from two feet per minute for slabs not over three inches thick. Of course, when thicker material is used the rate is slower.

The ordinary saws are thick and the teeth large. When smaller work is in hand finer saws are used and band saws may follow very crooked paths through the slate. Even slate screws and nuts are made for fastening pieces of slate together.

After an irregular piece of slate has been made of the desired size and shape it is taken from the sawing machine and transferred to the planing machine, Plate VII, by which the thickness is fixed and the surface made smooth. In both machines the cutting tool is stationary and the stone is moved against it. The planing is done by a knife very much like that of a wood plane except that it is stronger. Apparently, the knife easily does its work. At any rate it does it very rapidly and effectually. The common planer is replaced in some cases by a more complex machine for special purposes. For instance the machine shown in Plate VIII, is used for planing a series of similar pieces of relatively small size, as tiles and making them all of uniform thickness. In some mills, another modification of the planer not only planes, but cuts grooves in the slabs wherever they are desired.

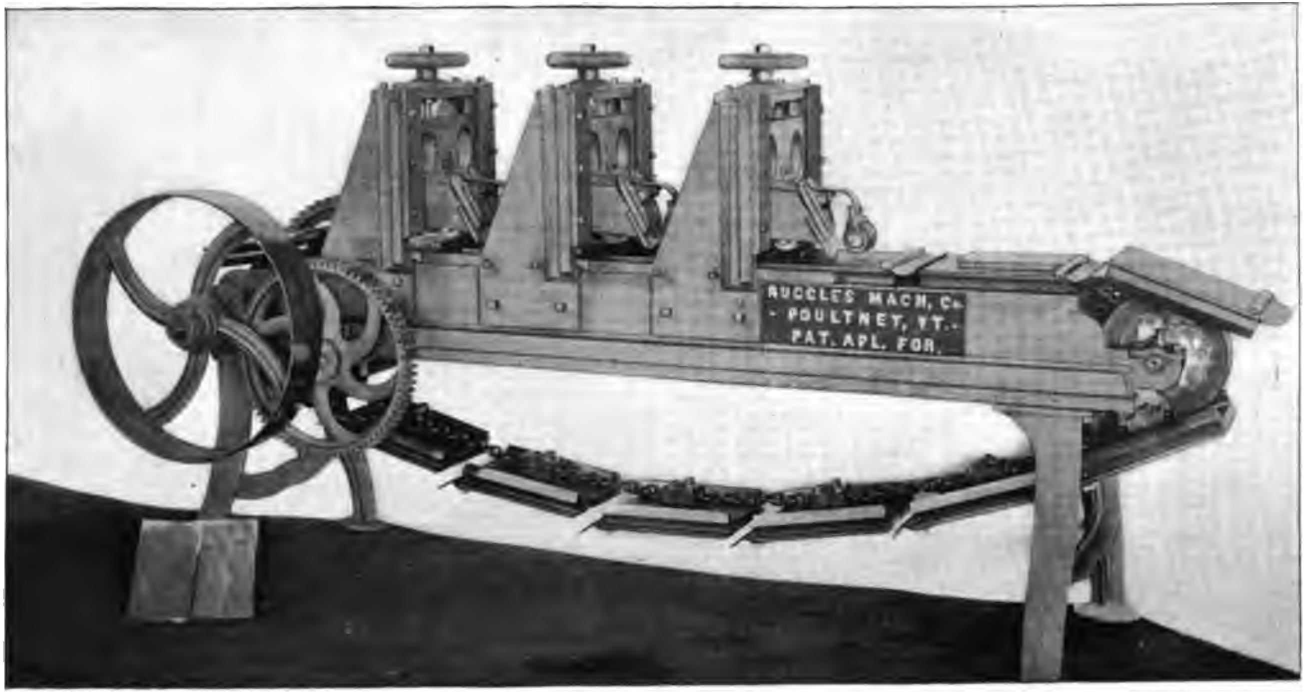
After the piece has been sawed and planed it is placed on a large, horizontally revolving iron disk on which, with sand and water, it is ground smooth. In some of the mills a further process known as "Marbleizing" is carried on. The slabs to be finished in this way are first rubbed smooth and coated with some sort of paint. Each is then skilfully held on the surface of a tank containing water, over the surface of which oil colors have been sprinkled and variously commingled. When the piece of slate is taken up the colors are found adhering to its surface. After they have been dried in a large hot chamber, the temperature of which ranges from 130°-160° F. they are taken out, coated and polished by hand, or by a polishing machine.

PLATE VII.



Slate Planing Machine.

PLATE VIII.



Slate Chain Planer.

The whole process as it is watched seems most easy and simple, but in reality only skilled workmen can produce satisfactory results. And the results are exceedingly satisfactory. I saw specimens of onyx and of different kinds of marble while by the side of each was the slate imitation and in many cases the copy was wonderfully perfect.

The uses to which slate is put are almost innumerable and all the mills reported large and increasing business.

GRANITE.

In the production and sale of marble, Vermont probably leads the world. In the slate business, though a long way behind Pennsylvania, we are far before any other state in the Union. Of late years the granite industry has been nearly as great as the marble, and during the year 1905 the sales of granite exceeded considerably those of any other stone. As has been noticed in previous reports, this now vast industry is of comparatively recent growth. Without doubt granite has been used to a small extent for foundations and walls ever since the State was settled, but it is not many years since the sales of Vermont granite grew large enough to attract attention. Not more than twenty-five years ago this industry was not regarded as especially important. In 1880 the total sales of granite in this State amounted to less than $60,000 and only twelve quarries are reported as then worked.

Statistical tables are not usually very interesting, but the following statement of the sales of granite in this State since 1890 is instructive in that it shows steady, though not wholly uninterrupted growth. As reported by the United States Geological Survey the value of the granite produced and sold in Vermont was as follows:

1890	$581,870.
1891	$700,000.
1892	$675,000.
1893	$778,459.
1894	$893,956.

1895	$1,007,718.
1896	$ 895,516.
1897	$1,074,300.
1898	$1,084,218.
1899	$1,212,967.
1900	$1,113,788.
1901	$1,245,828.
1902	$1,570,425.
1903	$2,350,000.
1905	$4,035,000.

For 1903 reports were received at this office from most of the principal granite workers, though many, chiefly of the smaller companies, did not report and from these figures I obtain as the total for that year $2,350,800, which is much larger than the amount given for the same year by the Geological Report of the Government.

I have before expressed my belief that the U. S. Reports have not done justice to our granite industry and given what seem to me good reasons therefor. The figures for 1904 are not so complete that I care to attempt to give a total as no effort was made to compile accurate figures for that year, but there can be no doubt that this would show marked increase over the previous year, but for the last year, 1905, I have more complete reports from the various companies than have ever come in before and, while the total amount is undoubtedly less than it should be or would be if all had reported, it is fairly accurate.

From the above figures the rapid growth of the business during the last three or four years is readily seen. It will also be seen that once in every few years, for some reason which may not in all cases be apparent, there has been a greater or less falling off in the amount of granite sold. It is also plain that on the whole the sales have steadily increased and no one at all familiar with the granite areas of the State and the conditions of the business can for a moment doubt that the increase is to continue and in all probability, the granite trade will not only grow larger with the coming of each new year, but the

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growth will be more rapid in the years immediately before us than it has been in the past. During the past year most of the granite companies have reported larger sales than ever before and many a very large increase, some having doubled their business. Many new cutting sheds are now in process of construction or have been recently completed, new and more efficient machinery has been or is to be installed, new quarries are being opened. When it is realized that with all the present prosperity, the natural supply of granite which Vermont possesses has not been really developed, but only partially explored by quarrymen and that great beds and masses have never been touched at all, it is easy to imagine that the granite trade of this State has almost unlimited possibilities before it.

During the past two years quite a number of the Barre companies have been united under and are conducted by a much smaller number of managers. There has been no tendency, so far as I am aware, to form any trust or to unite a large number of quarries or cutting plants under one management, but here and there, three or four independent concerns have been consolidated into one larger company.

Vermont produces all shades and grades of the gray granite from the very "Dark Barre" to the almost "White Bethel" with all sorts of intermediate shades in the Barre and Woodbury "medium" and "light." Some of the stone is suitable for the finest carved work or the most stately monument, while the product of many quarries has no superior and rarely its equal as a building stone.

It is I think safe to say that no known granite excels that found in Vermont for any purpose. Numerous and costly monuments and many of the finest and largest buildings in the country bear sufficient testimony to the truth of the above statement.

In the Report immediately preceding this, an account of the modern methods of working granite was given and in the same volume there may be found illustrations of a number of the quarries while Plates IX-XII, illustrate others. In the Third Report there is a detailed account of the "*Granite Area of*

Barre" by Mr. Finlay and in Dr. Richardson's paper "The Terranes of Orange County" there is a brief discussion of a part of the granite area of Barre and the interested reader is referred to these articles. In a following portion of the present Report, Dr. Richardson treats with greater fullness several of the granite deposits located in the territory of which he writes.

Thus far no red granite has been found in Vermont and it is not probable that any deposit of value can exist here, overlooked by all explorers. There is, however, a fine mass of pink, or pinkish, stone in the town of Newark which belongs to the Flint Granite Company of Albany, N. Y., and Newport, Vt.

Of this deposit the owners write as follows: "The character of the stone is very similar to that of Barre except that it has a pinkish color. We believe that it is without question the largest deposit of granite in the State of Vermont that is adapted for building and monumental work. The extent of the deposit is a mile and a half to two miles in length, and in height from thirty to a hundred and sixty feet perpendicular. The stone lies in sheets very nicely bedded, the layers are very heavy and vary from eight feet to thirty feet in thickness. It seems to be free from iron and imperfections."

Many of the Vermont quarries are able to furnish pieces of stone of any required dimensions. Indeed the size of pieces quarried may often be limited only by the capacity of the derricks and the possibility of transportation. I have seen slabs for the roof of a mausoleum taken from the Flint Quarry near Newport that weighed forty tons and quarries at Woodbury and Barre have produced those that were as large or larger. One of the largest single stones of which I have knowledge was quarried in one of the quarries now owned by the Boutwell-Milne-Varnum Company at Barre. This piece was detached from the bed rock, but not removed from the quarry. It was sixty-four feet long, thirty feet wide and eighteen feet thick. Its estimated weight was three thousand tons. It was all clear, good stock, and was cut up into pieces that could be handled.

Another yet larger piece of stone was quarried by A. E. Bruce & Sons. It was lifted whole from its bed, but, of course, could

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not be taken out of the quarry, until cut up. This block was thirty-nine feet long, twenty-five wide and forty-five thick, therefore was much heavier than the first named block. Such a block would weigh nearly four thousand tons.

During the past year quarries have been worked in greater or less number at Newport, Burke, Hardwick, Woodbury, Calais, Barre, Bethel, Ryegate, Groton and Dummerston. From this list it will be seen that granite occurs throughout the length of the State.

As several inquiries as to the strength of some of the Vermont granites have come to this office during the past year, I take this opportunity to refer the reader to Dr. Richardson's quotations of the strength of the Woodbury and Bethel granites given in the article following.

In the Fourth Report each granite locality was taken up separately and the chief details concerning it were given. Hence these may be omitted here as the main facts have not changed materially during the last two years. The main difference which is noticeable to anyone who visits the quarries and mills is in the larger work which is going forward. Perhaps the greatest single improvement in getting out stone from the quarries is found in the railroad constructed and set in operation during the last year by which the Bethel granite is taken from the quarries northeast of the village and carried a distance of five miles to the Central Vermont R. R. This adds a third to the already established railroads built solely to convey granite from the quarries to some main line. The road from Woodbury to Hardwick and the Barre Quarry Road with its numerous spurs into quarries have been mentioned previously.

The very recent development of the granite industry at Bethel which was described in the Fourth Report has gone forward with gratifying success. The demand for the Bethel granite is large and increasing and, as may be seen by reference to the result of tests given in the article mentioned above, the stone is not only one of the most attractive building stones to be found, but it is one of the strongest known. It is only three years since any work of importance was done at Bethel and yet during 1905 the E. B. Ellis and the Woodbury Granite Companies produced this stone to the value of nearly, or quite, three-quarters of a million of dollars.

The Woodbury Granite Company have a large cutting shed alongside of the Central Vermont's track a mile or so south of Bethel station, but the E. B. Ellis Company take all their stone to Northfield, 28 miles north as they already had a cutting plant there when the Bethel stone came into use and as water power, or rather electricity produced by water power, could be had there they find it better to carry all their stone to that place and ship from there.

Of the works at Northfield, one of the firm writes in answer to inquiry as follows:.

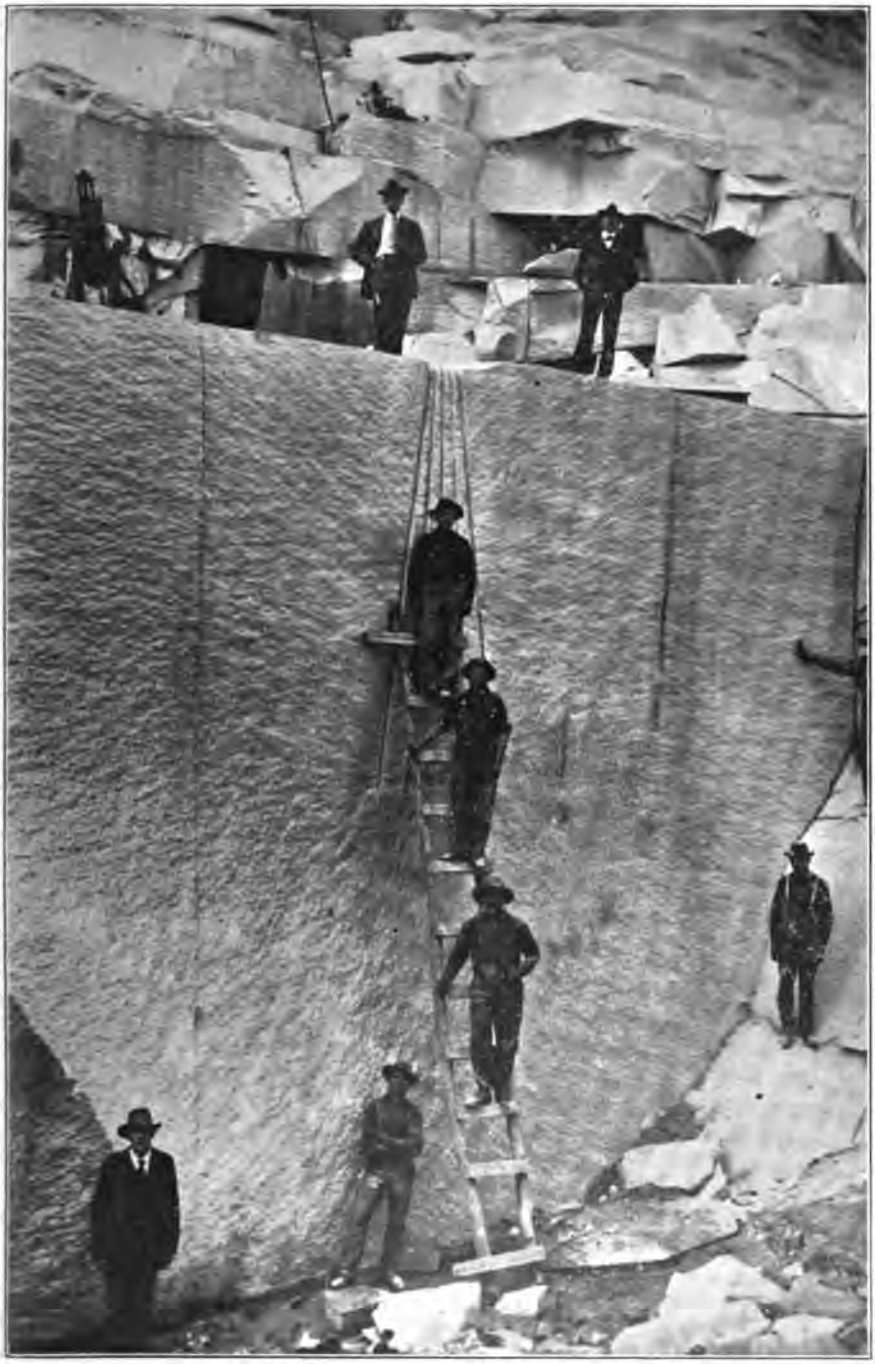
"Our cutting plant at Northfield is principally composed of three cutting sheds, situated on the line of the Central Vermont Railroad, one 350 feet long and 40 feet wide, another 230 feet long and 50 feet wide and the third 475 feet long and 50 feet wide. At the present time we are erecting an additional length to the second shed mentioned which will make it 475 feet long. These sheds are equipped with traveling derricks made by the Lane Mfg. Co., of Montpelier, Vt., of which we now have five in operation and another one about to be delivered which will be placed in the addition we are now erecting. We also have all the latest improved machinery known to the trade. Besides two column turning lathes now being operated we have recently ordered a column turning and fluting machine which will handle a stone seven feet in diameter and forty feet long, or equivalent to 196 tons. We are using over 300 H. P. to run our machinery, electric power being used throughout and is furnished from the Mad River Valley, a distance of ten miles from our plant.

The property of this company at Bethel covers three hundred acres. The quarry is equipped with eight twenty ton derricks worked by steam and numerous channelling and other machines worked by compressed air."

The Woodbury Company's quarry adjoins that of the Ellis Company and is on the same deposit which is of vast extent.

It is designed in the following list to give the addresses of all of the granite quarrying companies in the State and most of those

PLATE XI.



Section of a sheet 28 feet thick in the quarry of the Wetmore & Morse Granite Company at Barre, Vt.

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which are doing any considerable business in selling and cutting this stone though working no quarry. There are many small establishments scattered all over the State which do some business in granite and marble, chiefly in the manufacture of cemetery monuments and headstones which are not included. It is very likely that some are omitted which should be included, but from these no response has been received since the circulars of inquiry were sent out several months ago and consequently I have no certain knowledge that they are still in business. As it is the intention to publish similar lists in future reports, the author will be glad of any additions or corrections that may be made to the list as here printed.

Those marked Q work one or more quarries. Those marked C have one or more "Cutting Sheds." Q C indicates that the company have both quarries and cutting plants.

LIST OF COMPANIES QUARRYING OR WORKING GRANITE IN VERMONT.

BARRE COMPANIES.

Anderson & Sons, Barre, Q. C.
Allen & Newcombe, Barre, C.
Abbiati, E., Barre, C.
Barclay Brothers, Barre, Q. C.
Barclay, Andrew S. Co., Barre, C.
Barney, Auguste, Websterville, Q.
Barre Granite Co., Barre, Q. C.
Barre White Granite Co. Barre, Q.
Barre Granite Quarry Co., Barre, Q.
Beck & Beck, Barre, C.
Bedard, Joseph, Websterville, Q.
Bessey Granite Co., Barre, C.
Bianchi, Charles & Son, Barre, C.
Bilodeau, J. O. & Co., Barre, C.
Bird, Alex. & Sons, Barre, C.
Bond, G. E., Barre, C.
Bond & Kidder, Barre, Q. C.
Boutwell-Milne-Varnum Co., Barre, Q. C.
Bruce, A. E. & Sons, Barre, Q.
Brown, John & Co., Barre, C.
Bugbee & Alexander, Barre, C.
Burke Brothers, Barre, C.
Canton Brothers, Barre, Q. C.
Carroll & NcNulty, Barre, C.
Carusi, E. A. Barre, C.
Coburn & Ellis, Barre, C.
Cole, W. & Sons, Barre, C.
Comolli & Co., Barre, C.
Consolidated Quarry Co., Barre, Q. C.
Corskie, J. B. & Son, Barre, C.
D.B.L. Granite Co., East Barre, C.
Densmore, C. D., East Barre, C.
Dewey, Col. Cutting Works, Barre, C.
Dineen & Co., Barre, C.
Eclat Granite Co., Barre, C.
Ellis, H. M. Co., Barre, C.
Guidici Brothers & Co., Barre, C.
Grearson-Beckett Co., Williamstown, Q.
Harrison Granite Co., Barre, C.
Hoyt & Lebourveau, Barre, C.
Innes & Cruikshanks Quarry Co., Barre, Q. C.

Jones Brothers' Co., Barre, Q. C.
Jones, A. S., Barre, C.
Kidder, W. D., Barre, C.
Langfield Granite Co., Barre, C.
LeBarron, W. J., Barre, C.
Leland & Hall Co., Barre, C.
Littlejohn & Milne, Barre, Q. C.
McDonald & Buchan, Barre, C.
McDonnell & Sons, Barre, C.
McGee, William, Barre, C.
McIver, Mattheson & Co., Barre, Q. C.
McMillan C. & Son, Barre, C.
McMinn, J. & Sons, Barre, C.
Macchi, Z., Barre, C.
Magnaghi & Galli, Barre, C.
Manufacturers' Quarrying Co., Barre, Q.
Marciasi & Mortimer, Barre, C.
Marr & Gordon, Barre, Q.
Marrion & O'Leary, Barre, C.
Martell Brothers, Barre, C.
Martinson, John & Co., Barre, C.
Melcher & Hadley, Barre, C.
Milne & Odgers, Barre, C.
More, C. H. & Co., Barre, C.
Moore Brothers & Brault, Barre, C.
Mortimer & Campbell, Barre, C.
Murray, J.F., Barre, C.
Mutch & Calder, Barre, C.
Noonan Brothers, Barre, C.
North Barre Granite Co., Barre, C.
Novelli & Calcagni, Barre, C.
Oliver & Co., Barre, C.
Osborne & Son, Graniteville, C.
Parry & Sons, Barre, Q.
Pirie, J. K., Graniteville, Q.
Prospect Granite Co., Barre, Q.
Provost & Boussiere, Gouldsville, Q.
Pruneau & Giguere, Websterville, Q.
Rae, James & Son, Barre, C.
Rizzi Brothers, Barre, C.
Rizzi, L. G., Barre, C.
Robins Brothers, Barre, C.
Ross, Clifford & Co., East Barre, C.
Scott Brothers, Barre, C.
Sector James & Co. Barre, C.
Smith, E. L. & Co., Barre, Q. C.
Smith Brothers, Barre, C.
Standard Granite Co., Barre. Q.
Stephen & Gerrard, Barre, Q.
Straiton, George, Barre, C.
Sunnyside Granite Co., Barre, Q.
Sullivan, Eugene, Barre, C.
Sullivan, J. J. & Co., East Barre, C.
Summers & Co., Barre, C.
Swasey & Co., Barre, C.
Tayntor, C. E. & Co., Barre, Q.
Thom, Clark & Co., Barre, C.
Walker, Geo. & Sons, Barre, Q. C.
Wells, Lamson & Co., Barre, Q. C.
Young Brothers, Barre, C.

MONTPELIER COMPANIES.

Amer'n Granite Co., Montpelier, C.
Bertoli, H. J., Montpelier, C.
Bianchi Granite Co., Montpelier, C.
Bonazzi & Bonazzi, Montpelier, C.
Craven, E. E. & Co., Montpelier, C.
Dillon & Haley, Montpelier, C.
Doucette Brothers, Montpelier, C.
Frazier & Parkman, Montpelier, C.
Gill, C. P. & Co., Montpelier, C.
Gillander & Keough, Moutpelier, C.
Hill, Felix A., Montpelier, C.
Jurras, J. & Co., Montpelier. C.
McCann & Maroni, Montpelier, C.
Mills & Co., Montpelier, C.
Patch & Co., Montpelier, Quarry at Calais.
Pecue Brothers, Montpelier, C.
Pioneer Granite Co., Montpelier, C.

Plate XII.

Fletcher Granite Quarry, Woodbury, Vt.

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Ryle & McCormick Co., Montpelier, C.
Sibley, Clark, E. Montpelier, Q. C.
Sweeney Brothers, Montpelier, C.
Wetmore & Morse, Granite Co., Montpelier, Q. C.

COMPANIES LOCATED IN OTHER PARTS OF THE STATE.

Davis Brothers, West Berlin, C.
Daniels, Drew, Waterbury, C., Quarry at Calais.

Bruso, P. & Co., Northfield, C.
Cannon & Slack Co., Northfield, C.
Cross Brothers, Northfield, C.
Devine & Burns, Northfield, C.
Ellis, E. B. Granite Co., Quarry at Bethel, Cutting works at Northfield.

American Granite Co., Hardwick, C.
Anair, Joseph, Hardwick, C.
Crystal Brook Granite Co., Hardwick, C.
Daniels, T. H., Hardwick, C.
Donald, William B., Hardwick, C.
Fletcher, E. R., Quarry at Woodbury, Cutting plant at Hardwick.
Hardwick Polishing Co., Hardwick, C.
Jackson, H. B., Hardwick, C.
Mack, H. R., Hardwick, C.
Murch, E. R., Hardwick, C.
Ross & Imlah, Hardwick, C.
Stewart Granite Works, Hardwick, C.
Sullivan, J. E., Hardwick, C.
Tillotson, H. H., Hardwick, C.
Union Granite Co., Hardwick, C.
Valvola & Co., Hardwick, C.

Ainsworth & Mack, Woodbury, C.
Bashaw Brothers, Woodbury, C.
Brown & Drewen, Woodbury, C.
McNight, E. A., Woodbury, C.
Nolan, E., Woodbury, C.
Webber & Co., Woodbury, C.
Woodbury Granite Co., Quarries at Woodbury and Bethel, works at Hardwick and Bethel.

Anderson, A., South Ryegate, C.
Blue Mountain Granite Works, South Ryegate, Q. C.
Craigie, James, South Ryegate, C.
Gray, T. D., South Ryegate, C.
McDonald, M. F., So. Ryegate, C.
Metcalf, H. E., South Ryegate, C.
Morrison, D. A. & Co., South Ryegate, C.
Rabioli, J. D., South Ryegate, C.
Roben, Geo., South Ryegate, C.
Rosa Brothers, South Ryegate, C.
Ryegate Granite Works. South Ryegate, Q. C.

Benzie & Co., Groton, C.
Booth, C. L., Groton, C.
Carbee, W. R., Groton, C.
Coruth, G. E., Groton, C.
Darling, B. J., Groton, Q.
Frazier, Donald, Groton, C.
Gamble, John, Groton, C.
Hall Brothers & McDonald, Groton, C.
Hosmer Brothers, Groton, C.
McRae, Benzie & Co., Groton, Q. C.

Calais Granite Co., Calais, Q.

Lake Shore Granite Quarry, Calais, Q.
Lyon Granite Co., G. E., Brattleboro, Quarry and cutting plant at Dummerston, Q. C.

Chapman, W. J., West Concord, C.
Daniels, J. C., West Concord, C.
Grout Granite Quarry, West Concord, Q.
Kearney, Thos., West Concord, Q.
Burke Granite Co., West Concord, Q.

Tillcrop Granite Co., West Concord, C.
Welch, Joseph, West Concord, C.
Williamson, Harry, W. Concord, C.

Flint Granite Co., Albany, N. Y. Quarry at Newport.

Ayer, E. S., West Danville, C.
Goss, A. J., West Danville. C.
McGillie, West Danville, C.
Waldo, M. E. West Danville, C.

Goodell, J. W., Burlington, C.

In the preparation of the above lists I have been greatly aided by Mr. William Barclay, Jr., Mr. G. H. Bickford, Mr. H. W. Goodine and Dr. C. H. Richardson.

From the reports which have been received this year, though, as stated, quite a number of firms have made no report, there is at present capital invested in the granite business to the amount of $2,240,000, men employed 3,487, output for 1905 valued at $4,035,000.

CLAYS.

Brick yards are common all over the State, but aside from these, the clays of Vermont are not largely used.

Still there are a few establishments which dig and sell an amount which is quite worth considering.

A short distance southeast from Rutland there is a deposit, or rather there are several, of a peculiar clay which has apparently resulted from the breaking down of the mica schist which is common in the region. Some of the schist is talcose and this produces a somewhat different clay from that which is more micaceous and some of it is also more siliceous. The *Rutland Fire Clay Company* dig these different sorts of clay and use them, either alone or mixed, for various purposes. A certain mixture of two sorts of these clays proves to be a most excellent fire clay and a considerable quantity of this is sold for furnace and stove use.

Other portions of the deposit are mixed with cement and other substances and sold for wall plaster and the company have received the highest testimonials to the good qualities of this material. The deposit has as yet been hardly more than opened and there appears to be an ample supply for future use. About a mile and a half from the clay beds the Company have a milling plant where the clay is ground, mixed and put up for sale.

At Forestdale, a village in the town of Brandon, Messrs. *Horn, Crockett & Company* have works which were described in the last Report, in which kaolin is prepared for sale. The clay is dug from a deep shaft near the mill and is very white, but contains a good deal of quartz sand which must be removed. A large quantity of clay is dug and sold when dried and ground.

At Shaftsbury, *Messrs. S. C. Lyon and Brothers* dig and sell china clay, kaolin and ochre.

In Monkton there is what appears to be a large deposit of kaolin which has been explored somewhat and some years ago a company undertook to work it, but owing to the death of the principal in the movement all work was stopped after a time. As to the deposit I am informed by Mr. M. O. Snow, a well driller, that he was employed several years ago to sink six inch borings into the kaolin bed in order to ascertain something as to its thickness. Mr. Snow sank six holes varying in depth from 41 feet to 174 feet. In all the borings kaolin was found in abundance. In the deepest boring the kaolin was reached at a depth of 16 feet and followed down to 174 and the bottom not then reached. In the 154 feet shaft, 38 feet of kaolin was found.

MARL.

In this connection there may be noticed a bed of Marl which is of large extent and good quality.

By invitation of Mr. E. H. Deavitt I visited the deposit early in the fall of 1905. The bed is in the town of Sutton and covers about ten acres of a swampy tract of land. The bed appears to be continuous and of varying thickness from five or six feet near the outer portions to over twenty feet in the middle. The marl is very pure white carbonate of lime and contains remains of planorbis and, to a less extent, other shells of fresh water mollusks.

Where it has not been dug off, there is a covering of peaty soil which varies from a few inches to a foot and a half in thickness. Analysis of specimens which I have obtained has been furnished by Mr. F. M. Hollister of the Vermont Experiment Station.

Analysis of Shell Marl from Sutton.

	As received.	Dried.
Moisture	30.00 per cent	
CaO. Calcium Oxide	33.56	47.96*
MgO. Magnesium Oxide	25	36.
Insoluble matter	62	88.
Iron and Aluminum, traces.		

TALC.

Talc mining has been carried on of late with unusual activity, and several new beds have been investigated and are now worked. The bed which has been worked for some time by the *International Mineral Company* at Moretown is thus far the largest deposit found in the State. At this place preparations have been made for not only getting out the talc, but for grinding it and preparing it for market. The talc is shipped at the Central Vermont Station at Middlesex and this necessitates a haul by team of some six miles.

At East Granville the *Eastern Talc Company* have a shaft which was opened in 1904. The stone is taken from a depth of a hundred feet and carried by team to the railroad which is not far distant. Here it is shipped in the rough to mills in Maine.

At the time of my visit, June, 1906, forty tons a day were mined.

At some distance south of this shaft a new bed is being opened. In Rochester, the *United States Talc Company* are working a talc mine and shipping the material.

*Equivalent to 85.58 per cent. carbonate of lime.

The *American Mineral Company* have control of a deposit of talc which is a few rods south of the railroad station at Johnson. This property had not passed beyond the prospecting stage when I saw it, but it appeared very promising.

The talc mass cropped out over a considerable area and borings indicate that it has, at least in places, a thickness of many feet. The quality is good there being little or no grit or other impurity.

SOAPSTONE.

This material is quarried and manufactured to some extent in the southern part of the State, but I have received no reports from any of the companies engaged in working it.

PEAT.

A very unusual degree of attention appears to have of late been given to the peat beds of the country. The difficulties which arise every now and then in the coal fields and the consequent increased price of the different kinds of coal are probably in a large measure accountable for this new interest in peat. At any rate if any permanent results come out of investigations into the getting and uses of peat, Vermont ought to have a share in it and reap some benefits from it for peat is abundant in all parts of the State. I presume that there are few of our towns that do not possess at least one peat bed and many have several. On account of its geological character, Vermont will never possess a coal mine because the rocks of this State were nearly all formed long before the first coal bed began and the conditions in this region during the coal making times were such that it was impossible that any beds of coal should be deposited here or near here, but ages later, when peat deposits began, the conditions were very favorable for large and numerous deposits.

As to the value of peat, the following, quoted from Professor Norton of the Mass. Institute of Technology may be of interest. "Its caloric value when dried is from 6.600–1.400B.T. units per pound. This compares very favorably with good grades of coal, both anthracite and bituminous, very little of which will give out 2400 heat units to the pound. With the proper preparation and advantage of mechanical pressure when drying, marsh mud should average 1200-1400 heat units to the pound, which would place it considerably above run-of-mine coal of high grade. For domestic use peat briquettes seem to be in every way as good as anthracite and in some respects better than any kind of bituminous coal.

They are free burning, give a clear, smokeless flame, they are clinkerless and hardly need any draft when started.

The cost of digging, preparing and drying peat is much cheaper and safer than coal mining, being all on the surface and requiring neither skill nor experience. Marsh lands are of much greater extent than coal areas. * * * * * * Vast beds are found in New England. Their development will render independent of coal supplies many inland localities where other cheap fuel will never be available."

While as it seems to me, the case for peat is put in the above statements quite as strongly as facts will warrant, even when the peat is of the best quality, yet there is undoubtedly much truth in what is said and much that should attract attention. It is not by any means impossible that on many of our farms which today yield but poor returns for the labor spent upon them, there are peat beds that may, with improved methods of preparation and use, prove much more remunerative than do the crops which are now raised on what are regarded as the more valuable parts of the farms.

For some time Mr. F. M. Hollister, Chemist at the Vermont Experiment Station, has been investigating the peat of the State. This work has not yet reached conclusions that can be published.

While, as has been noticed, peat deposits of some sort are found almost everywhere in this State, yet Mr. Hollister reports that "Some of the most extensive deposits are in Benson, Monkton, South Hero, Pearl, Isle La Motte, South Burlington, Williamstown, Marshfield, Franklin, Bennington. The most extensive deposit in Vermont is probably in and around Bristol Pond about two and one-half miles from Bristol station.

It is my impression that a good share of Vermont peat is of the decayed wood variety and that a good many such deposits exist without the knowledge of their owners. At Franklin the so called Cranberry Marsh seems to be an almost inexhaustible deposit of half decayed sphagnum moss suitable for moss litter."

In the Report of the U. S. Geological Survey on Mineral Resources of the U. S. Mr. H. H. Hindshaw says of peat.

"The uses to which peat may be put are almost unlimited. Artificial wood, in the shape of ornamental panels, was shown at St. Louis Exposition. It is mixed with wool to make "Sanitary Underwear" and various grades of paper have been successfully made. A cattle food is made in England by saturating peat meal with molasses and a flourishing industry has thus been established. This food is said to be becoming popular in the United States. As a disinfectant and deodorizing agent of the first order, the merits of peat are beyond question. It has for years been used in hospitals and public buildings in England and continental Europe. It is used for hospital beds and mattresses as well as for bedding for horses. Its power to absorb ammonia is many times greater than that of straw, and by its use stables can be kept free from odors. The principal interest, however, in peat is as a source of fuel. In its crude condition peat has proved both in this country and Europe to be useful only under exceptionally favorable conditions and within a very short distance from the source of supply. It has been tried on many of our railroads as a substitute for wood or coal, but no record of its extended use can be found, its great bulk and high water content always defeating its application."

The great trouble with peat seems to be the very large amount of water it contains and the great difficulty of removing it.

The writer just quoted has the following in regard to the use of peat tor the manufacture of gas:

"Another form in which peat is coming into use and which may before many years prove the best means of using it, is as a gas. The large proportion of volatile carbon makes it excellent material for the manufacture of illuminating gas and as a producer of gas the peat bog will soon, with the rapid development of the modern gas engine, outrival the mountain stream as a source of power and its use will not destroy the most beautiful objects of natural scenery, but will on the other hand, redeem the dismal solitude of the swamp.

Much attention has been given to peat in Canada for several years past the object chiefly sought being to produce compressed briquettes. The business is still in an experimental stage, but some quantity of peat has been put on the market and has sold at a price giving a large profit to the manufacturers." That it is entirely possible to use peat as a fuel is shown by the following experiment made on a California railroad. "A train of ten cars was run over the same track a distance of sixty miles, first with coal and then with peat briquettes. There were used 4,450 pounds of coal and the time consumed was two hours and forty six minutes. The run with peat briquettes was made in two hours and forty one minutes and 5,100 pounds of fuel were used."

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ASBESTOS.

For several years much attention has been given to the asbestos deposits in this State. That there is much of scientific as well as practical interest in these beds is certain.

What the future of the asbestos industry in Vermont is to be it is not possible to predict. There is unquestionably a large amount of this valuable mineral in certain parts of the state, but thus far it has not been found sufficiently concentrated to make mining profitable. That is, the veins of asbestos are in all cases, so far as yet found, enclosed in so large a quantity of very hard rock that crushing and separating necessary to get the fibre in marketable condition has been too costly. Another difficulty is that all the deposits are at a considerable distance from the nearest railroad.

In all the veins so far discovered the fibre, while in many cases it is of good quality, has been very short. Still, this would not prevent profitable mining if it only formed a sufficiently large percentage of the total rock taken out.

At present none of the asbestos mines are being worked.

In the report preceding this, there is an article on the chief asbestos area in this State. "*A preliminary report on a portion of the Serpentine Belt of Lamoille and Orleans Counties by Professor W. F. Marsters**," in which the geology and mineralogy of the region is discussed with some detail. It was Professor Marster's intention to carry on his work and publish the results in this report, but an unexpected call to Peru prevented the plan from reaching completion. Some additional material, however, was published after the last report appeared in a bulletin of the Geological Society of America and, while most of this is of value mainly to special students of rocks, I have yet thought it worth while to reprint such portions of the paper as did not appear in the Vermont report. For the use of the accompanying illustrations I am greatly indebted to the Geological society.

After describing in general the areas studied, as may be seen in the last report, Professor Marsters goes on to consider the types of

*Fourth Report, Vt. State Geologist, pp. 86-102.

rock found as follows: (Bulletin Geological Society America, Vol. 16, pp. 417-444.)

GENERAL DISTRIBUTION.

"Within the area under consideration three widely different types of rock are to be found, namely, schist, amphibolite, and serpentine. The first occupies the valley floors and lower slopes of the Missisquoi; the second forms the uppermost 1,000 feet of Belvidere mountain, and the third occupies the area between the schist and the amphibolite.'

SCHIST.

Brief discussion of composition.—It will be seen from an inspection of the map showing the distribution of a part of the formations of the State that the Belvidere area lies entirely within the so-called talcose schist as mapped by Hitchcock and published in the report for 1861.*

On account of the lithological characters and mineralogical associations the schists of Vermont were early regarded by Hitchcock and others as a part of the great terrane extending from southeastern Canada (Quebec) to Alabama. Among the first scientific men to devote attention to these peculiar rocks was T. Sterry Hunt, who carried on a series of chemical investigations with the hope of gaining some knowledge of the origin of this rather prominent series of metamorphics as they appear within Canadian territory. His studies led to the conclusion that they were derived from slates. His chemical results, moreover, brought out the fact that the name "talcose" as applied to the schists was a misnomer. The fact is evident from an inspection of his analysis, which is appended:

Silica	66.70
Alumina	16.20
Proxyd of iron	6.90
Lime	.67
Magnesia	2.75
Alkalies (by difference)	3.68
Water	3.10
	100.00

*Edward Hitchcock: Geology of Vermont, vol. 1, p. 504. Map, vol. 2.

Thus it is seen that less than 3 per cent of magnesia is to be found in this sample (Saint Marie), and even in the slates with which the talcose schists are closely associated not more than 8 per cent. It is thus evident that, in so far as the Canadian representative is concerned, the above term is not at all applicable.

The announcement of these results stimulated further study of this same problem within the limits of Vermont. The investigations of Mr. G. H. Barker under the directions of the state survey produced similar results. The specimens analyzed came from Roxbury, Pownal, and Middlesex respectively.

The name "talcose" as applied to the Vermont schists is also an unwarranted term, although it is to be said that talc and talcose lenses are not uncommon within the limits of the schist formation.

Age of the schists.—As to the age of the schists, various interpretations have been offered. If I am correct in correlating the schists, with which the asbestos bearing serpentines are associated in Quebec, with the occurrence under consideration, the Vermont series would be regarded by the Canadian geologists as belonging somewhere in the Quebec group.

The term "Quebec" is applied to a large series of metamorphics, including slates, schists, and serpentine deposits. It is probable that it, in reality, included both Cambrian and pre Cambrian rocks. Moreover, the occurrence of graptolites within the limits of the Quebec group also shows that it includes rocks of Ordovicic age as well. Where in the series the schists and the associated serpentines belong is not yet clear from the evidence at hand. It has been stated by the Canadian Survey that the schists are in all probability Cambric in age.

The southern extension of the schists, as represented in Old Hampshire county, Massachusetts, and Windham county, Vermont, has been studied in very great detail by Professor Emerson. Using the Vermont geological map as the basis for comparison, the talcose schists of Vermont are continuous with the Goshen schists of Franklin and Old Hampshire counties. This terrane is considered as Siluric by Emerson. Inasmuch, however, as the United States Geological Survey did not adopt the term "Ordovicic," as suggested by Lapworth, for Lower Silurian in the nomenclature of geologic folios until this year, it should be noticed that the term "Silurian" as used by Emerson probably includes rocks of Ordovicic or possibly earlier age. If this interpretation be correct, it is clear that the Quebec group of the Canadian Survey and the Silurian as used by Emerson may overlap or include one or more formations of one and the same age—that is, the upper members of the former may be synchronous with the lower members of the latter; but to what extent they may be chronologically parts of the same formation cannot be determined with the data at hand. Such evidence as can be obtained from the literature suggests that the Vermont series may be the late Cambric or early Ordovicic in age.

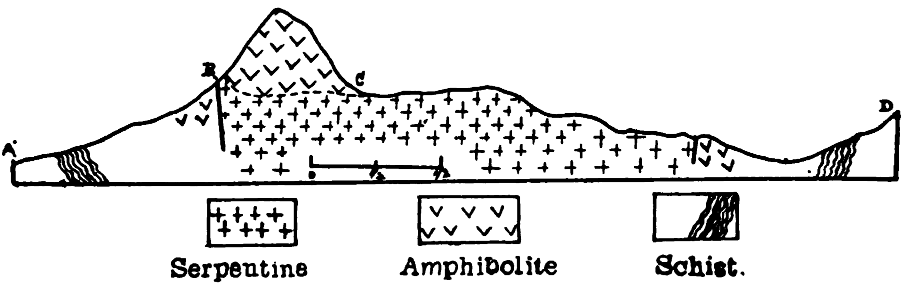


FIG. 1. Section through Belvidere Mountain.

AMPHIBOLITES.

Areal distribution.—An inspection of the map of the Belvidere region, Figure 2, will show that the main area of amphibolite is confined to the uppermost 1,000 feet of the mountain crest at the southern terminus of the ridge. This rock probably makes up the tip of the ridge as far as Hazens notch; how far it may extend beyond has not been determined.

Small but important exposures of the same rock occur at the lower edge of the serpentine and in prospects opened up by Judge Tucker. There are thus three areas; but the two smaller ones are particularly important, inasmuch as they provide certain data which it is believed will make clear with reasonable certainty the true lithological relationships of the amphibolite and the serpentine and the origin of the latter.

At the south end of Belvidere the amphibolite forms the steep sloped portion above the plateau-like terrace.

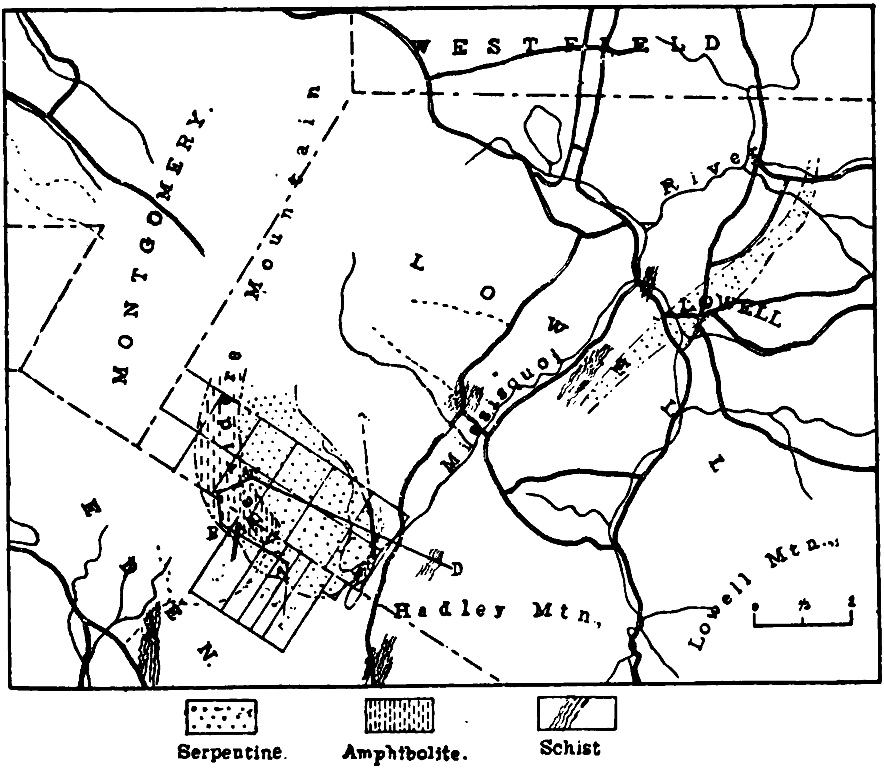


FIG. 2. Map of Eden, Lowell, etc., showing Serpentine Area.

Macroscopic characters and mineral composition.—A very large portion of the rock is composed of dark green hornblende, so arranged with respect to the cleavage of the individual components that a gneissic and, at times, a decided schistose structure is fairly well defined. At the base of the hornblendic mass, or just above the level of the rimming plateau referred to, the amphibolite presents an additional phase in becoming highly garnetiferous.

The relation of the garnet-bearing zone to the underlying serpentine is not easily determined, as the probable contact is covered by waste from the cliffs above. At a few points in the rear of the plant of the New England company garnet was recognized as high as 70 feet above the foot of the talus slope. So abundant is the garnet at various points along the base of the cliff that the rock assumes a marked reddish color and thus, at first sight, might be regarded as quite distinct from the normal amphibolite. From this point upward the garnet gradually disappears. Above the 70-foot mark (barometric determination) it could not be detected in any of the hand specimens with the unaided eye. The microscope, however, reveals the fact that garnet does occur in small amount above this height. The main mass is nevertheless confined to the base of the amphibolite, and probably represents a local contact phenomenon. Its extent, so far as known, is indicated on the map of the Belvidere region.

The texture of the normal amphibolite is quite variable. At the top of the ridge it is a fine grained mass, with occasional bands of feldspathic minerals and a tendency to split in planes parallel to the minute mineral constituents, 90 per cent of which is hornblende. Half way down the slopes on either side of the highest point the rock assumes a finely fibrous texture. This seems to be a local condition, and does not extend through any great thickness in the central portion of the formation. Again, along the fault on the southwest side of the mountain the amphibolite takes on a fibrous and, at times, a lamellar structure. This also is quite local, it being induced by the crushing and shearing consequent on the faulting. The main body of the formation is moderately coarse in grain, showing cleavage planes 6 and 7 millimeters in length and 3 or 4 in width. It is not uncommon to find in cross-sections of individual hornblende crystals a marked blending or curvature, best shown in sections along the longer axis. The cleavage conforms very closely to one direction, so that the rock splits very easily into plates with an apparent schistose structure. Both pyrite and magnetite grains have been detected with the unaided eye, but in most cases they are in very small amount.

The remaining exposures of amphibolite do not differ in any respect from the typical representative of the coarse grained type, already described. In both exposures there is clear evidence of marked crushing and shearing, particularly in the exposure on the brook as shown on the map. Unfortunately these areas are very largely covered beneath gravel and waste from the slopes, so that it is impossible to determine the extent and relationship of these two small but important exposures. The details of the contact of the amphibolite with the serpentine, as shown in the Tucker quarry to the north of the brook section, will be discussed later. It is sufficient to state here that this contact is believed to furnish sufficiently clear and unmistakable proof of the intrusive origin of the rock from which the serpentine has been derived.

SERPENTINE.

Macroscopic characters and mineralogy.—The serpentine is remarkably uniform in texture throughout the entire area. It is rather fine grained, grayish green to dark oily green in color and splintery or hackly in fracture. On freshly broken surfaces it is not uncommon to discern a tendency to assume a lamellar or more often a fibrous texture. The fibrous tendency is invariably associated with zones of shearing and possible thrust. In the upper part of the serpentine belt this texture is most evident along a zone passing through the open cuts of the New England Mining Company. When examined under a hand glass it will be seen that much of the fibrous content of the rock is in reality confined to minute seams and shearing planes and stretched out along the line of movement. It would thus seem that the fibrous content, inasmuch as it fills cracks and seams, even of microscopic size, must be secondary in origin. The stretching of the so-called fiber is due to subsequent slipping after the deposition of the mineral within the original fracture. The same conditions obtain at various points. It is very well shown in the prospects of the United States Company (Blake property) 250 feet below the mill of the New England Company, as well as in many of the openings made by Tucker, Stone and Farington along the lower edge of the serpentine deposits. Occasionally on the fresh fractures minute lamellar structure may be seen. Under the hand lens they appear to be small silvery to light-green scales, but too small for specific determination. On the basis of structure it is reasonable to conclude that these minute individuals may be some form of the lamellar serpentine, to which the name Antigorite has been applied. It is to be regretted that sufficient material is not at hand to determine this point.

In the Tucker prospects, however, considerable variation in color and an appreciable range in texture is noticeable. The color varies from light grayish green to oily dark green, and brilliant dark green when wet. Scattered through the mass are many patches of magnetite, with which is associated a very small amount of chromite. It is in the Tucker quarry that the best showing of cross-fiber in this serpentine area can be seen. The dark bands of serpentine are intimately associated with the fiber-bearing veins. They form the adjacent walls, and vary in width with the size of the vein from one to several inches. When the veins form a minute network the whole mass may assume the dark oil green color and then form large bands and blotches 2 or 3 feet in diameter. This peculiar association, so far as observed, is confined to the prospects of the Tucker property.

Local talc lenses.—The main part of the serpentine deposit is a fine grained light grayish green rock, sometimes exhibiting a tendency to become talcose, and wherever this occurs it is accompanied with a slight schistose structure. In fact, on the line of the cross-section, at a point about 150 feet below the edge of the plateau, a number of talc bearing lenses may be seen. They contain moderately pure talc in the centers, but grade out into the normal serpentine on either side with loss of the schistose structure. From an economic point of view, they are too small to invite any investigation.

STRUCTURE OF THE REGION.

The structure of the region is indicated in the accompanying cross-section. Amphibolites form the upper 1,000 feet of Belvidere, and include the steep slopes extending upward from the crescent-shaped plateau, the latter being composed of serpentine.

At the juncture of the two rock types is a band of garnetiferous amphibolite. An important fault occurs on the west side of Belvidere. This was first recognized by Professor J. F. Kemp. How extensive the faulting may be was not determined. It is to be said, however, that certain features in the topography of the western slopes suggest that series of faults may occur to the north and may have been a determinative factor in the minuter topography of this unique and picturesque ridge. On the eastern slopes no faults were detected. Much local crushing and local shearing is evident within the limits of the serpentine. Such shear zones are intimately associated with the so-called asbestos. On the Tucker property, at the foot of the plateau, are to be found certain structural facts which at first suggested the occurrence of a zone of crushing and shearing. At this point a contact between the serpentine and amphibolite is unmistakably clear. This was at first regarded, on the basis of a field observation, as a fault, the crushed zone of serpentine forming a very favorable depository for the cross-fiber. It will be shown, however, that the contact of the serpentine with the amphibolite does not represent a fault plane, but an igneous contact. The development of a crushed zone adjacent to the contact is necessarily a subsequent phenomenon. The remaining instance of a possible contact relationship is to be found a few hundred yards to the south of the preceding case. Its location is shown on the accompanying map. Here crushed amphibolite was found within a few feet of the serpentine. Whether, as in the preceding case, an igneous contact or a simple fault zone may exist here could not be determined with any degree of certainty, but it is believed the former is the case. Unfortunately the greater part of the rim or foot of the plateau is buried beneath a coat of waste and till, which renders further discovery of structural relationships well-nigh impossible.

Protruding through the till may be seen excellent exposures of the surrounding schists, which form the valley floors and subordinate ridges in the immediate vicinity. It maintains a very steep dip, with a strike varying from nearly true north to north 20 degrees east. A considerable variation in the lithologic characteristics of the schists obtains. The variation may be marked in a comparatively short cross-section. Bands of micaceous rocks, which at times are apparently talcose to a slight degree, are followed by sandy schists, including small lenses of quartz, with an appreciable amount of pyrite. No limestones were found in the vicinity of Belvidere. The positions of a few of the outcrops noted are indicated on the map. The structural features, in conjunction with the mineralogy of this formation, favor the view that at least a large part of this terrane is sedimentary in origin.

DEVELOPMENT OF CANADIAN INDUSTRY (THETFORD).

In this country and Canada chrysotile was not known to exist in any quantity until the seventies. It was discovered in Canada long before this date, for in 1862 specimens of Canadian chrysotile were exhibited at the International Exhibition in London, England. It was then regarded as a mineralogical freak rather than a product of great economic importance. In a report of the Canadian survey of 1847—1848 reference is made to its occurrence in serpentine rock in the region of Bolton. But, while the extension of the belt of serpentine rocks in which this mineral is known to occur had been traced with some care from the Vermont boundary in the township of Potton to and beyond the Chaudiere river, the deposits of asbestos observed were comparatively limited. In the United States veins generally of short and harsh fiber were found at several points, and a considerable quantity of a tremolitic variety was mined, which, while ill adapted for the purpose to which asbestos is now generally applied, was used for the manufacture of fireproof paints, cements, etcetera. The chief source of supply for fibrous asbestos was the mines of Italy, where deposits of irregular extent occur, the mineral often possessing a long and silky fiber, which well adapted it to spinning, and from this source the material for fireproof curtains and similar manufactures was obtained. In 1877—1878 asbestos was discovered in the serpentine hills of Thetford and Coleraine. The size of the veins, often several inches thick, led to the expectation that deposits of value might exist there, though their true importance was not ascertained for several years. The credit of the discovery in this locality is claimed by Mr. Robert Ward, though by others it is stated that the first find was made by a Frenchman named Fecteau. Following closely upon the discovery several parties secured areas both at Thetford and Black Lake, in Coleraine township, on the line of the Quebec Central railway, which for some miles runs . . . between high ridges of serpentine, in which, the timber having been burned off, the veins were observed at the surface by the weathering and felting of the mineral on the surface on the bare rock.

From this time (1878) on the industry developed with the demand for the product. Early in the nineties the region became the leading producer of the world, and holds that position at the present time. In 1903 the United States produced but 2.4 per cent of the value of the imported product. This condition should stimulate the most strenuous search for so valuable a product.

KINDS—SLIP-FIBER AND CROSS-FIBER.

While it is universally true that chrysotile is confined to serpentine, it is by no means true that all serpentine deposits contain it. Although the Belvidere area is a difficult one to investigate as regards structural details, sufficient data have been obtained to demonstrate with reasonable certainty that the fiber contents are very largely restricted to certain belts, the localization of which is due to structural features confined to the serpentine deposits. In the open cuts and prospects made, especially by the New England Asbestos Mining and Milling Company and others near the upper contact with the amphibolite, the fiber, when in sufficient quantity to be easily detected, shows that it is largely confined to a shattered and sheared zone of rather limited extent. In the central part of the zone are large masses with slickensided surfaces. Wherever cross-sections of these could be found careful examination revealed the fact that they in turn were also sheared, and could with a little careful manipulation be separated into a series of smaller wedge-shaped masses, each with smoothed surfaces. It is along these planes that the fiber has attained its maximum development. It occurs in two forms, and has been recognized by the local prospectors. In a large part of the zone of shearing the fiber has stretched or pulled out along the slipping planes, and hence has been called "slip-fiber." In certain parts of the area, however, there has been a maximum development of fracture with minimum shearing. In such fractures the fiber has assumed a transverse position, and is locally known as "cross-fiber." The same phenomena may be seen in thin sections prepared from smaller blocks.

With regard, therefore, to the structural details bearing on the areal distribution of the fiber the facts as they now appear force the conclusion that the fiber will be limited to the zones of fracture and shearing. How many of these exist within the serpentine zone under consideration is a difficult matter to determine. Enough data are available, however, to indicate that a zone fracture with marked shearing crosses the property of the New England company. It is probable, too, that a smaller one crosses the property of the National company. A third belt of fracture with minimum shearing occurs on the property of Judge Tucker. This case is adjacent to the igneous contact to be discussed in another section. The fiber is largely of the "cross-fiber" type. It has the color and luster of true chrysotile. Under the blowpipe it behaves in all respects like the fibrous form of chrysotile. It yields considerable water and is nearly infusible. There is a tendency on continuous application of the flame for very fine films or strands of the fiber to become noticeably brittle. The cross-fiber was, however, quite uniform in its behavior before the blow-pipe. Still one or two samples did not yield as much water as should be expected in true chrysotile. How prevalent this may be has not been determined.

The "slip-fibre" differs from the "cross-fiber" in having a duller and waxy luster, less flexibility, and a tendency to develop a coarser but longer strand, sometimes reaching 3 inches in length, while the latter rarely attains 1 inch in length. Under blow-pipe tests the slip-fiber yields much less water and fuses, with some difficulty, to a white enamel. The color test for calcium was also evident. These reactions strongly suggest that the slip-fiber is not true chrysotile, but a fibrous form of amphibole. This variety, however, is on the market as asbestos, but its market values are much less and its uses not so great in range.

At the lower contact of the serpentine with the amphibolite on the Tucker property is the best showing of cross-fiber seen in the entire belt. It is only just to say, however, that it does occur as well on the land of the New England company, but in very small amount. While cross-fiber is the more prominent of the two sorts, shearing, which seems to be a constant associate with the slip-fiber, is by no means absent in the Tucker exposures. It is confined, however, to very narrow zones. On the other hand, the cross-fiber is very largely confined to the borders of the thrust zone, and, so far as could be seen from the new exposures, occupied a greater breadth or area than the zone of thrust. Nowhere in the field are small slip-blocks better developed than at the Tucker contact. The surface has been polished and sometimes covered with a fibrous film of hornblende, which has been stretched or pulled out in the direction of movement. In consequence of the shearing the trituration of the blocks upon each other has produced alternate sharp angles around the greatest periphery, with alternating obtuse edges roughly in a plane at right angles to the plane of the former and along its greatest diameter, or as many as three obtuse angles may occur on each flat surface of the block. In cross-section minute partings may be seen lying roughly parallel to the trend of the surfaces and filled with glistening films of fiber—that is to say, the strain to which these masses were subjected was so great that they in turn were also fractured and subsequently knitted together by the deposition of silky fiber.

STRUCTURE OF CROSS-FIBER VEINS.

A cursory examination of any block containing typical cross-fiber veins shows that they usually occur in groups of bifurcating and rejoining members, usually associated with one or two larger members not exceeding one inch in diameter.

In thin-section of even the microscopic veins, magnetite and probably a small amount of chromite are found to be constant associates. Pyrite was also recognized, but in very small amount. In the hand specimen it would appear that the magnetite was confined very largely to the central portion of the individual vein. In thin-sections of the smaller veins this relationship is not so evident. On the contrary, sections may be selected in which there seems to be no localization of the metallic contents, which are scattered throughout the entire width of the fiber band and extend well into the body of the serpentine. This, however, is not the rule, but rather the exception. From the material at hand I think we may safely conclude that the ores have a decided tendency to accumulate with the central zone of the fractures, while the deposition of the fiber favors the walls.

DISCUSSION OF PROBABLE MODES OF GROWTH.

The method of growth of the fiber and its relation to the ores is a vexed problem. Whether this deposition begins on the walls and gradually pushes its growth towards the central space and finally coalesces along a central line or whether the fiber develops simultaneously along its entire length is not easily demonstrated. If the latter were true and the deposition of the ores were contemporaneous with the growth of the fiber we should not expect to find a tendency toward central localization of the metallic contents, for the chances for uniform deposition at all points within the crevice would be equally good. It is true that such conditions can be found, but do not conform to the general plan observed.

On the basis of the first hypothesis, if we assume that the fiber began its growth on the walls of the fracture and pushed its way toward the center, then we should expect an increasing amount of ore deposition in the central portion, with the infringement of the fiber from the sides. As a matter of fact the ore does, in the majority of cases seen, favor a central position, as if the circulating waters which carried the ore were compelled to move in a central zone. It follows, then, as a consequence of this sort of growth that a coalition and knitting together of the opposing ends as they came in touch should result. Moreover, it would seem that the line of juncture should be detected in cross thin-sections, for it would be most remarkable that the growth of opposite individuals or strands should have the same optical orientation and unite in such a way where not interfered with by the deposition

PLATE XIII.

FIGURE 1.—SECTION (87) OF TYPICAL AMPHIBOLITE FROM THE LOWER CONTACT ON THE TUCKER PROPERTY.

Section shows crushed epidote in a mass of partly altered hornblende.

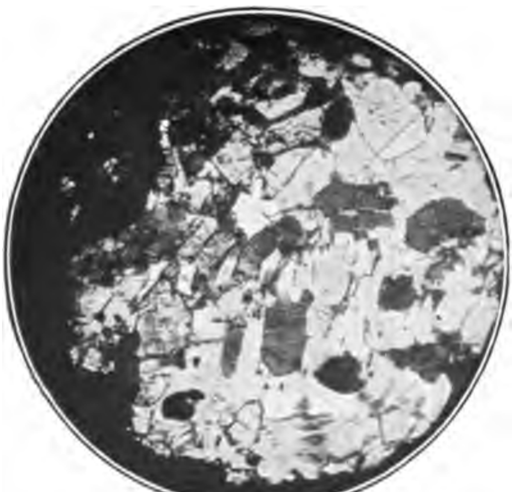
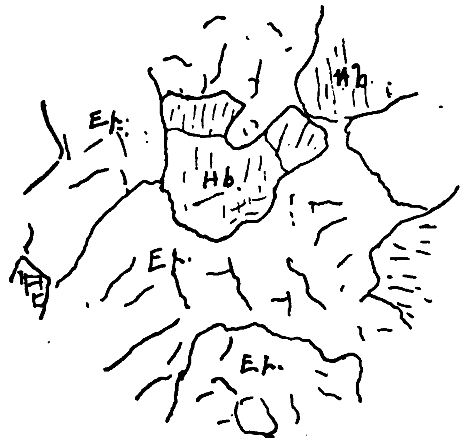


FIGURE 2.—AMPHIBOLITE (SECTION 45) CONTAINING LARGE AMOUNT OF GRANULATED EPIDOTE EMBEDED IN CRUSHED HORNBLENDE.

PHOTOMICROGRAPHS OF AMPHIBOLITE.


Ep.
Hb.
Hb.
Ep.
Ep.


Ep.
Ep.
Hb.
Ep.
Ep.
Hb.

of iron ore, as to appear to be one and the same individual. In the sections at hand I have not been able to detect this relationship, but it is believed that further study of the problem may show that this interpretation is in the main the correct one.

It might be said that the deposition of the ores was subsequent to the growth of fiber and along secondary fractures within the body of the latter. It is true that the fiber-bearing veins have been sheared, for it is this process that has produced the slip-fiber. This supposition may be true, but it still remains that veins which do not show any evidence of shearing or fracture also contain much magnetite in central partings or as rods and bunches parallel to the strands; hence in such cases there was no opportunity for the subsequent deposition of the ore. While it must be admitted that sufficient material and data are not at hand to solve the problem, it is believed that such facts as we have favor the interpretation as expressed in the above hypothesis.

AMPHIBOLITE.

MICRO-STRUCTURE AND MINERALOGY.

Plates XIII and XIV.

In the predominant type of amphibolite hornblende is far in excess of all the other constituents combined. It makes up from 79 to 90 per cent. of the entire mass. In thin-section the hornblende appears as large individuals, roughly columnar in outline and from 5 to 8 millimeters in length. They are sometimes intimately interlaced or grouped in bundles. Judging from the cleavage surfaces as seen in the hand specimen, one is surprised that the cleavage partings are not more prominent in the thin-section. In sections normal to the vertical axis the cleavage partings are well defined, but in the prismatic and pinacoidal zones, while in instances easily recognized minute hair-like lines, often fading out and reappearing again, may still be so fine that a higher power is necessary to make this structure clear and evident. There is also a rude transverse parting, which in the main should correspond in direction and position to the plane of the basal pinacoid (001). The pleochroism is unusually strong. It ranges from a greenish yellow parallel **a** to bright green on **b** and blue on **r**. This is a characteristic feature of the hornblende in amphibolitic schists.

Not infrequently the hornblende shows evidence of decomposition and passage into secondary products. In most cases the decomposition product is ordinary chlorite, but transitions into penninite are not uncommon. It can be recognized by its deep purple interference color, which does not appear in any other member of the chlorite group. In its passage to chlorite the typical cleavage of the original is lost and a scaly or lamellar structure occurs. Very minute inclusions may be also recognized. They lie in two positions—either parallel to the prismatic cleavage or normal to it. Occasionally larger individuals may be indiscriminately scattered through their host.

In addition to the hornblende there occurs a variable percentage of light colored to colorless silicates. A large portion of these constituents is orthorhombic epidote or zoisite.

The lack of extinction angle and prevalence of low interference colors, not exceeding those of the first order, serve to distinguish it from monoclinic epidote, which exhibits an extinct angle and interference colors approaching the third order. In most sections the greater part of the colorless silicate is zoisite. Two cleavages are prominent, one lying parallel to the long axis (*c*), the other a prominent transverse parting at right angles to the former and sometimes fading out before traversing the entire width of the individual. Inclusions are present, but no systematic arrangement is prominent. They are usually too small to make specific determination with any degree of certainty. In a few cases, however, it is comparatively easy. The peculiar pink tint and rhombic outline of faces as may be seen under a high power (240) show that some of these inclusions, at least, are minute garnets. They are confined to the central portion of the host. On account of the predominance of the optical properties of the host the isotropic character of the garnet is completely overshadowed. In addi-


Hb.

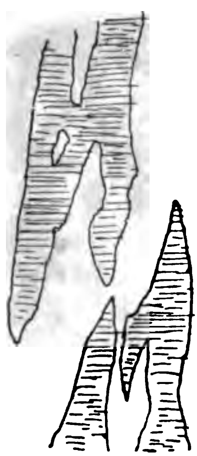


PLATE XIV.

FIGURE 1.— PHOTOMICROGRAPH OF SECTION 89
Showing the cross-fibre and bifurcation of the amphibolite veins. The relation of the parts is such as to strongly suggest fracturing by shear-pressure.

FIGURE 2.— SECTION (4) *A*) OF TYPICAL COARSE AMPHIBOLITE
Showing the curved cleavage partings in a large hornblende.
PHOTOMICROGRAPHS OF AMPHIBOLITE.

tion to them are many rod-like and acicular inclusions, the identification of which, however, is not an easy matter.

The remaining light colored silicate is epidote. It may occur as grains, produced in part by crushing, or in rudely columnar masses with ragged ends and irregular sides, the individuals sometimes attaining a length of 4 or 5 millimeters. The maximum extinction angle observed was 11 degrees.

Two cleavages are present, one parallel to the long axis and poorly developed, the other a transverse parting clearly exhibited on account of the rather strong refraction so characteristic of this mineral.

Very little pleochroism is recognizable. In most cases it is colorless, but occasionally a slight tinge of yellow is apparent.

Very minute inclusions are arranged parallel to the long axis, but are quite too small for specific determination. Magnetite is an omnipresent accessory, or probably a secondary product resulting from the decomposition of some of the essential components. There are also present small wedge-shaped or irregular grains, which behave in all respects like titanite.

LOCAL VARIATIONS.

Garnet zone.—There are certain local variations in the mineralogy of the amphibolite which should be noted at this point. The exact geographical distribution of this feature has not been worked out in the fullest detail, but, so far as can be determined from the field observations and collections at hand, the greatest deviation from the normal type occurs along the line of contact with the serpentine, best seen back of the plant of the New England company and again along the fault on the west side of the mountain, the position of which is indicated on the geological as well as the traverse map. The former is a zone of variable width, lying at the base of the amphibolite cliffs and characterized by the development of a very large amount of garnet, easily detected by the unaided eye, and in patches so abundant as to give the rock a reddish hue. In thin sections various stages of alteration to chlorite are evident. The well developed crystalline outline so characteristic of fresh and unaltered garnet is largely destroyed. Such fresh grains of the individual as may remain are usually surrounded by rims of green to yellowish-green chlorite. With it are associated small amounts of secondary quartz and feldspar, which permeate the cracks of the original garnet and also form rims at the periphery of the individual. Indeed, the alteration may be so complete that no trace of the original garnet is evident, and there remains only the general outline. In such cases the central portions are chiefly composed of chlorite, while the outer portions are occupied by the quartz and feldspar. In nearly all cases the chlorite belongs to the variety penninite. It should be added that garnet is not confined to the zone indicated on the map. Several sections from points well up the western slope, as well as near the top on the eastern side, show garnet changed to penninite. The amount is very small and probably local in development.

Development of anthophyllite.—Along the fault line already referred to there are some modifications of the normal amphibolite worthy of detailed study. While the fault is sharply defined—about midway of the line as indicated on the map—It can nevertheless be traced a short distance above and below by a breccia zone. The amphibolite along this zone has taken on a schistose and somewhat fibrous texture. The original hornblende has been crushed and granulated to such an extent that the primary structure has been largely obliterated and the mass now in part altered to chlorite. Embedded in the chlorite mass are numerous fibrous individuals, with ragged terminations and fairly well defined prismatic boundaries. No pleochroism is evident. A transverse and longitudinal cleavage is easily detected. The former is the more prominent of the two. The relief is quite strong, and hence the interference colors are correspondingly high. The lack of extinction angle, the high interference, and absence of pleochroism places the mineral with the orthorhombic amphiboles. It is regarded as anthophyllite. The section (45) containing the mineral was found in line with the extension of the fault. Its position is shown on the traverse

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PLATE XV.

Fig 1.

Fig 2.

Photomicrographs of Serpentine.

map. Embedded in the rock are also many grains of garnet, now altered to penninite. It is not improbable that the garnetiferous zone may extend to and beyond this point, and that the anthophyllite is consequent upon the shearing, and hence entirely local in distribution.

The remaining amphibolite localities occur at the Tucker quarry and again on the little brook a few hundred yards to the south. In both cases the rock belongs to the normal type. In the latter, however, there is abundant evidence of crushing, thus suggesting that a sheared zone or line of faulting might be near at hand. No clean contact could be found. Typical serpentine occurs within a few feet of the amphibolite exposure, but owing to the density of the forest and the heavy covering of loose materials the interval between these two points could not be seen.

SERPENTINE.

Plates XV. and XVI.

CRITERIA FOR DETERMINING ORIGIN.

In the previous investigations of serpentine and its probable origin it has been found that by far the greater number of cases on record are regarded as having been derived from some form of basic eruptive. The interpretation rests on the possible preservation and recognition of remnants of mineral constituents belonging to the original mass, or in cases of complete alteration, at least, the retention of some of the characteristic and determinative structures belonging to the essential minerals of the original rock.

MICRO-STRUCTURE OF BELVIDERE SERPENTINE.

Types.—On the above basis the following types of structure have been established as proof of the kind of rock from which the serpentine was derived.

(1) *Mesh structure*, in serpentine derived from olivine.

(2) *Bastite structure*, in serpentine derived from enstatite or bronzite.

(3) *Lattice structure*, in serpentine derived from non-aluminous hornblende.

(4) *Knitted structure*, in serpentine derived from non-aluminous augite.

In the Belvidere serpentine, however, serpentization is so far advanced that the recognition of original structures belonging to minerals of the original rock is rendered well-nigh impossible in the majority of cases. There are, however, a few sections which shed some light on this most interesting question.

In sections of the normal and fine grained serpentine two distinct types of micro-structure can be seen—one, a very complete fibration of the rock, the other assuming a noticeable lamellar phase or possibly scaly habit. If structure alone is the only essential element necessary upon which to recognize and classify serpentines, the latter should be regarded as lamellar or antigorite serpentine.

Fibrous serpentine—In the fibrous group at least two distinct arrangements of the fibres may be seen, with all gradations between; in one the fibres are arranged in parallel series and in bundles; in the other they show a marked tendency to diverge at the ends or to radiate from centers, and sometimes even to interlace. More than one phase may appear in a single section. According to the interpretations of A. Lacroix and others, the variations in structure may be and are used as a legitimate basis for the establishment of distinct mineral varieties. If these varietal forms, however, are crystallographically and chemically one and the same thing, it would seem to be undesirable to give specific names because of variation in form alone.

The greater part of the Belvidere area shows a markedly fibrous structure. No particular arrangement is characteristic of any limited part of the area. Coarse and fine textures may be found in the same prospect. The parallel and radiate arrangement may be found in the same section. According to Rosenbusch, the parallel arrangement is regarded as the chrys-

PLATE XVI.

Photomicrograph of Serpentine (Section 42)
Showing the divergent arrangement of fibrous structure of the serpentine.

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otile variety, while the radiate is characteristic of picrolite and the divergent phase of the metaxite variety. The parallel and divergent structure is fairly well shown in sections numbers 7 and 57, from pit number 2, United States company. Section 42 shows a very good case of the divergent and interlaced arrangement, while the lamellar or antigorite variety is well illustrated in sections 43 and 58.

Lamellar and bastite serpentine.—While most of the sections from the serpentine area show the characteristic fibrous aggregates common to thoroughly serpentinized rock, there are in certain sections some additional features, which are believed to throw some light on the probable origin of the original mass. Some of these features are shown in sections 51 and 69. It is not uncommon to find a series of parallel laminæ making up an individual crystal. In some cases grains or stringers of magnetite may be distributed along the partings. In all cases parallel and perpendicular extinction is obtained. These individuals appear like secondary masses derived from an orthorhombic pyroxene, probably some such mineral as enstatite. In other words, the secondary mass is bastite, a pseudomorphous product which is so common in members of the gabbro family. It would thus seem probable that the original rock from which the serpentine was derived was a massive igneous rock in which an orthorhombic pyroxene formed an essential member.

DISCUSSION AS TO ORIGIN.

CONTACT PHENOMENA.

The locality yielding the most important facts bearing upon the probable origin of the rock from which the serpentine was derived is the contact on the Tucker property. The contact is clear and well defined. Near the line of junction the serpentine is almost isotropic. When examined, however, in parallel polarized light and under a sensitive tint there appear minute fibrous and block-like individuals, which suggest an actual crystalline structure. At the immediate contact the serpentine assumes, under cross-nicols, a deep ultra-blue color. This area includes a part of the absorbed edge of the amphibolite, for the individual components of the amphibolite may be traced by gradations into the blue areas, where they finally lose their optical characteristics. In other words, these facts show that the amphibolite has been absorbed by an intruded igneous rock. The somewhat slaty and baked character of the amphibolite on the immediate contact bears out this conclusion. In sections of the serpentine at a short distance from the contact the fibrous aggregate structure appears again as in the normal type from other parts of the area.

It should be stated here that the above contact was at first regarded as a simple fault.* That crushing of the serpentine, as well as the amphibolite, has taken place is admitted; but if the contact is of the nature of a fault alone, brecciation should form a prominent factor in the thin-section. This does not appear, but the phenomena of absorption and infusion of the amphibolite are the prominent features. The fracturing of the serpentine and the adjacent hornblendic rock is to be attributed to a subsequent movement, with which was associated the deposition of the asbestos.

APPLICATION OF EMERSON'S VIEWS.

An alternative is to be considered in discussing the probable origin of the serpentine. It has been shown by Professor Emerson that orthorhombic pyroxenes develop in limestones by processes of metamorphism and also along contacts of igneous or intrusive masses with lime-magnesia rocks. The question therefore arises with regard to the Belvidere serpentine. Might not the bastite (enstatite) in this case represent a transition stage in a rock, originally sedimentary, high in lime and magnesia and containing a variable percentage of iron? It has

*The crushed and broken character of the serpentine observed in the region of the contact on the Tucker property was regarded as sufficient evidence of a true fault, and was so stated in my Preliminary Report in the Vermont Geological Survey, 1903-1904, page 96. Further detailed study of thin-sections makes it reasonably certain that the crushing of the rock was a subsequent phenomenon, which provided favorable conditions for the depositions of the "cross-fibre."

been shown by Professor Emerson† that the above relationships occur in Old Hampshire county, Massachusetts. Moreover, it should be stated that this area lies in the same geological province with the Belvidere area. Emerson also demonstrates that not only the serpentine is derived from the pyroxenic calcareous rocks, but that the amphibole rock—amphibolite—is also a metamorphic product derived from the same series. In other words, both the serpentine and the amphibolite are, according to his interpretation, secondary products resulting from processes of metamorphism of magnesia-bearing limestones, and not of igneous or intrusive masses. The succession of changes from the original sedimentary rock to the final secondary products, as suggested by Emerson, are shown in the following tabulated scheme:

Original rock.	*First stage.*	*Second stage.*	*Third stage.*	
	Pyroxenite limestone.	Sahlite serpentine (tremolite).	Serpentine (steatite).	Talc.
Ferruginous and	Enstatite limestone.	Enstatite serpentine (actinolite, bastite, tremolite).	Serpentine	Talc.
Argillaceous	Amphibole limestone.	Amphibolite (epidote).	Serpentine	Talc.
limestones.	Tremolite limestone.	.. ..	....	Talc.
		Olivine serpentine (tremolite).	Serpentine (asbestos).	Talc.

At the present stage of investigation of the Belvidere region it can only be said that neither the amphibolite nor the serpentine has been found in associations with limestones or highly calcareous rocks of any sort which would in any respect show an analogy with the occurrences in Old Hampshire county, Massachusetts.

†Monograph xxix, U. S. Geol. Survey, pp. 78-117.

ANALYSIS OF TYPE ROCKS AND FIBER.

An inspection of the following analyses and comparison with those of chrysolite from the Canadian area bring out some significant facts.

Number	Sio_2	Al_2O_3	Fe_2O_3	FeO	MgO	H_2O	Cao	Total
45...	41.84	....	....	2.23	41.99	14.28	....	100.34
48...	40.57	0.90	....	2.81	41.50	13.55	....	99.33
49...	40.52	2.10	....	1.97	52.05	13.46	....	100.50
1...	39.97	7.27	....	....	40.78	12.51	0.50	101.03
2...	44.10	....	....	....	43.00	12.90	....	100.00

Numbers 45, 48, and 49 are analyses of chrysolite from Shipton, Quebec, Broughton, and Templeton, and are selected from a series in Dana's Systematic Mineralogy, page 673.

Number 1. Belvidere chrysolite (cross-fiber) from the Tucker prospect; analysis by Mr. C. H. Jones, Burlington, Vermont. Both the oxides of iron and the aluminum are included under the 7.27 per cent.

Number 2. Theoretical composition of chrysolite, as given in Dana's Systematic Mineralogy, page 673.

In the Belvidere fiber number 1 it will be noted that the silica runs somewhat lower than is indicated in the Canadian cases and considerably lower than the theoretical limit, while the total alumina and iron is, on the other hand, much higher than in numbers 45, 48, and 49. The iron is probably somewhat high, for the reason that the fiber contains microscopic grains of magnetite tucked away between the films to such an extent that its removal by the use of a magnet may not have been complete.

The mechanical inclusion of the ore would necessarily lessen or lower the percentage of the other constituents.

The analyses of the serpentine, in which the asbestos is included, require brief consideration. To this series is also added the theoretical composition of serpentine as given by Professor Kemp in his "Handbook of Rocks," and two analyses of the amphibolite which forms the crest of Belvidere mountain.

Number	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	H_2O	Total
1...	44.14	....	....	42.97	....		12.89	100.00
90...	40.21	5.73	....	40.98	0.82		12.68	100.42
35...	40.82	7.63	....	38.40	1.37		12.41	100.63
5...	42.93	32.77	....	5.96	14.29		1.76	97.71
23...	44.36	28.85	....	8.84	11.70		1.71	95.36

Number 1. Theoretical composition of serpentine. Kemp's Handbook of Rocks, page 140.

Number 90. Analysis of serpentine frôm foot of the serpentine slope, Belvidere mountain.

Number 35. Analysis of serpentine from the upper slope and taken from the property of the United States company.

Number 5. Analysis of amphibolite from the base of the formation CO_2.

Number 23. Analysis of amphibolite from the top of Belvidere present but not determined. It accounts for the low total.

An investigation of the analyses of the serpentine, when considered in the light of theoretical composition, brings to light some variations needing a word of explanation. It will be seen that the silica runs noticeably below the theoretical limit, and in fact below that usually found in many serpentines derived from pyroxene or olivine rocks. This can be accounted for by the fact that the rock almost invariably shows a large amount of iron ore, and probably by far the greater part of the total estimate of the alumina and iron is composed of iron oxide. This, as in the case of the fiber, would lessen the relative amount of silica in the analysis.

The presence of a small amount of alumina is to be accounted for as well. It is already a recognized fact that alumina cannot be considered as an introduced product, but, to the contrary, must have formed a part of the original rock from which the serpentine was derived. Now, the facts gathered from the thin-sections suggest as the original a rock containing an orthorhombic pyroxene. The very large amount of magnetite precludes a derivation of the pyroxene by metamorphism of limestones or highly calcareous deposits. If this interpretation be correct, we are forced to conclude that the original from which the serpentine was derived must have been some member of the gabbro family. The alumina, therefore, could be derived from the presence of an aluminous pyroxene, or more probably from the feldspar. The calcium could likewise be derived from the same sources. The thin sections suggest that a very large part of the calcium is now present as carbonate. It is not, however, universally present in all sections.

CONCLUSIONS.

It is believed that the petrographical facts, as obtained from the thin-sections of the serpentine-amphibolite contact on the Tucker property, are sufficiently evident to render the application of Professor Emerson's explanation of similar deposits impossible. It must be admitted that a number of the thin-sections from the serpentine area show an appreciable amount of calcite. But an excess of calcium carbonate is by no means a proof of a derivation from a limestone. It is quite as easily accounted for as a secondary product from pyroxenic contents of an eruptive or igneous mass.

It is also significant in this connection to note that petrographic and chemical investigations of serpentine deposits, both in the United States and other countries, have almost invariably proven that such rocks are derived from some member of the basic igneous series. The accompanying tabulation of explicit statements, culled from the literature, contains but two cases of a derivation from a pyroxenic limestone out of a total number of twenty-six occurrences. While this statement contains nothing of the nature of proof with reference to the area under consideration, it nevertheless reveals the significant fact that the conclusions reached with reference to the Belvidere serpentine are quite in accordance with the predominant views held by the vast majority of petrographers.

Concerning the origin of the amphibolites, I can also say that so far as lithological relationships in the field and petrographical characters are known no data have been found which even offers a suggestion as to the nature of the original rock from which the amphibolite was derived. It is not, however, associated with any argillaceous limestone, such as has been recognized by Professor Emerson, in the Old Hampshire county occurrences.

Locality.	*Analysis derived from.*
Colfax folio, California	Peridotite.
Downieville folio, California	Peridotite, pyroxenite.
Jackson folio, California	Peridotite, gabbro, pyroxenite.
Mother Lode folio, California	Intrusive, original, not determinable.
Placerville folio, California	Peridotite, pyroxenite.
Sonora folio, California	Basic gabbro or ultra basic rocks of the peridotite family.
Moriah, New York	Pyroxene.
Aqueduct, New York	
Montville, New Jersey	Saxonite.
Grenville, California	Pyroxene rock.
Mount Diablo, California	Peridotite.
Blandford, Connecticut	Sahlite in limestone (Monograph 29, U. S. G. S.)
Granville, Connecticut	Enstatite in limestone (Monograph 29, U. S. G. S.).
Kamloops, British Columbia	Basic volcanics.
Ishpeming, Michigan	
Roseburg folio	Saxonite and olivine gabbro.
Lassen peak	Dunite.
Holyoke folio	Associated with limestones.
Mosquito Range, Colorado	Pyroxene and amphibole.
Russia	Olivine and diallage rock.
Southwest Minnesota	Saxonite.
Roxbury, Vermont	
Manhattan Island, New York	Actinolite, tremolite.
Rainy Lake region	Olivine eruptives.
Nevada City and Grass Valley, California	
Sierra Nevada	Gabbro (dike) peridotite.
Coast range, California	Peridotite (see 177*a*).
Marquette region	
Elkhorn district, Montana	Alteration product from diorite.
Baltimore, Maryland	Enstatite olivine rocks.

SCHIST.

The Pike Manufacturing Company have quarries in this State from which they obtain a schist. Scythe and whet stones are made from this. The Vermont industry is only a branch of the large business done by this firm, the offices being at Pike, N. H.

MINING.

As has been repeatedly noticed in former reports, mining is not a very important part of the mineral industry of this State.

At present, the only mineral deposit which is vigorously worked is one of Chalcopyrite in East Corinth, at Pike Hill.

After some years of idleness, this deposit was reopened some months ago and now about seventy-five tons of ore are daily mined and carted to Bradford whence it is shipped to smelters. The Superintendent informs me that a new mill has been erected and probably ore will be reduced on the spot before these pages are in print. The Elizabeth mine at South Strafford is also being worked to some extent. The old Ely-Goddard mine, which for years was a famous copper producer, has not produced anything for some years and is now unworked.

For a somewhat detailed account of the mineral deposits at Bridgewater and of gold mining there the reader is referred to the last Report, page 54 et al.

At my request Dr. C. H. Richardson of Syracuse University has been acting as field assistant for the past four years. His article on the *Terranes of Orange County* was included in the Third Report. The article in this volume carries on the same study and over a larger area. It is expected that Dr. Richardson will continue this investigation of the geology of Northeastern Vermont and present the results of his work in future reports.

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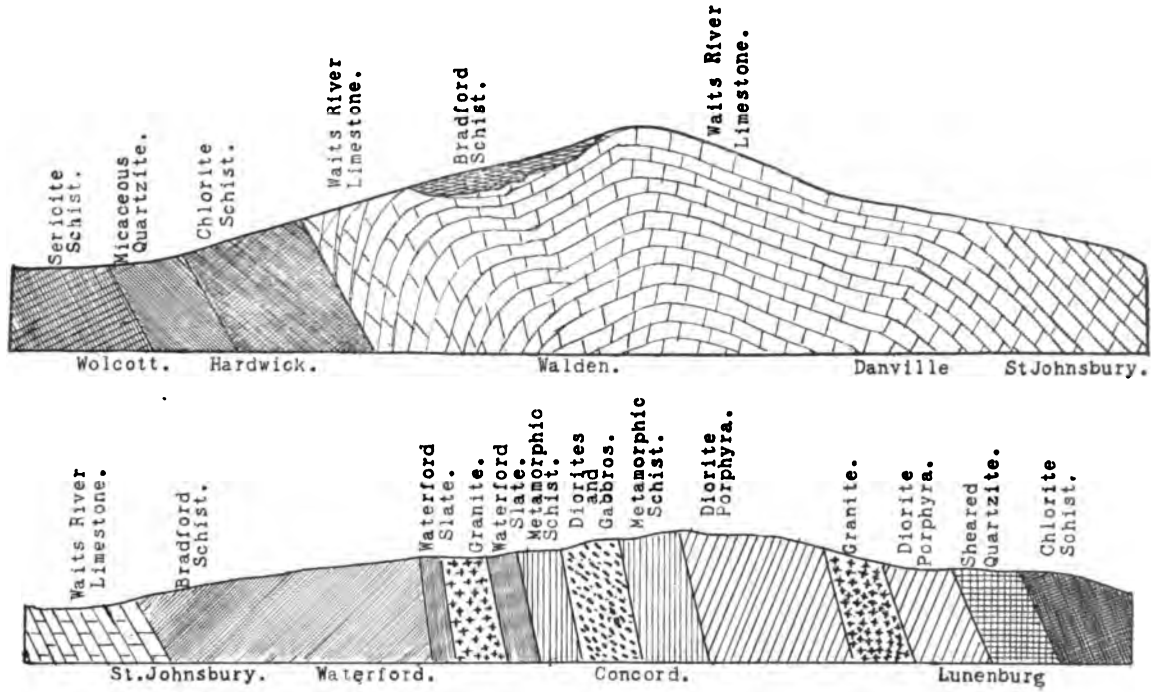
PLATE XVII.



Section from east to west across a part of North Eastern Vermont.

Vertical Scale 1:15,840.
Horizontal Scale 1:250,000.

The Areal and Economic Geology of Northeastern Vermont.

C. H. RICHARDSON, Syracuse University.

INTRODUCTION.

The present report upon the Areal and Economic Geology of Northeastern Vermont must be considered as a report of progress. When invited to study the North Country in 1904 it seemed possible to present in this Fifth Report of the State Geologist a detailed resume of all work done and required in the section assigned.

Time forbids accurate mapping and the plotting of the structural relations. These can be accomplished only in a generalized way without continued research in the field. The report therefore might be fittingly styled A Reconnaissance in Northeastern Vermont. The area chosen comprises Caledonia, Essex and Orleans counties with fifty-two townships, forty-one of which have been traversed. It includes also a small portion of Washington County.

Many photographs have been taken, a part of which appear as half tones in this article while the remainder are in the possession of the State Geologist. Two hundred and twenty-two carefully selected typical rock specimens of uniform size, have been placed in the State Museum at Montpelier where both names and localities can be easily ascertained. Out of many of these, microscopical slides will be prepared for petrographical study, the results of which may be embodied in the next biennial report.

The only map (Plate XXIII), accompanying this report is a stratigraphical map representing a protracted section extending from the Connecticut River on the east through the pre-Cambrian and Ordovician terranes to the pre-Cambrian schists on the west. Its original trend is to the northwest nearly at right angles with the average strike of these northeastern formations, N.40° East.

A marked unconformity of bedding and cleavage planes is occasionally found, as on the south side of Kirby Mountain, therefore the cleavage lines in the section may or may not conform with the planes of bedding. The bibliography, a large part of which appeared in the Third Annual Report of the State Geologist, 1901-1902, is here repeated, because it contains many new references to articles upon the geology of this or kindred areas.

I wish also to recognize my indebtedness to Prof. C. H. Hitchcock of Dartmouth College for suggestions offered and instruments loaned in the summer of 1904 and 1905; to Dr. George P. Merrill, Curator of the National Museum, Washington, D. C., for assistance in the identification of a part of the irruptives; to Dr. George Otis Smith, United States Geological Survey, Washington, D. C., for timely suggestions; and to the Geological Faculty of Johns Hopkins University for their kindly assistance in many ways.

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PLATE XVIII.

Barnet Falls.

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RAILROADS.

Six railroads pass through the narrow valleys of Northeastern Vermont. The Montpelier and Wells River Road operating between the two points named follows the transverse valley of the Wells River, passes between the Blue Mountain granite in Ryegate and the Groton granite, thence through a most excellent timber land over a large area of granite in Marshfield in Washington County to Montpelier. It is also a natural outlet for the Barre granite.

The St. Johnsbury and Lake Champlain Road, extending from Lunenburg on the east to Maquam on the west, is the great outlet for the Woodbury and Hardwick granite of Washington County, and the Kirby granite of Caledonia County, also the lumber in an extensive area on Kirby, Waterford, and Miles Mountains.

The Boston and Maine Road, Passumpsic Division, winding its way up the Connecticut and Passumpsic River Valleys from White River Junction to Newport, its northern terminus within the State, not only affords connection with Montreal and Sherbrooke, its northern terminus in Canada, but it is also the outlet of the Barton, Salem, and Newport granite.

The Grand Trunk Road entering the State from the east at Brunswick passes through a densely wooded section over a granitic area through Brighton, Morgan, and Norton into Canada.

The Maine Central Road only skirts the northeastern corner of the State in Lemington and Canaan, and does not, like the preceding roads, pass through a densely wooded section or over a granitic area.

In addition to these five roads the Hardwick and Woodbury Road should be mentioned. This is a branch owned and operated by the Woodbury Granite Company for the hauling of its large output of granite from the quarries on Woodbury Mountain to the village of Hardwick where it is manufactured. The granite industry is the basis of the economic life of several towns. This is especially true of Hardwick and South Ryegate. Without it hundreds of people now earning their daily bread in the quarries or stone sheds would be engaged in other industry, the railroads would lose a large portion of their valuable freight profits, and the State a large part of its productive resources.

DRAINAGE.

The drainage of Northeastern Vermont is toward the four cardinal points of the compass. The height of land lies from twenty to twenty-five miles south of the International boundary. The general line of high altitude passes through Newark, Sutton, and Craftsbury. To the north the drainage is through the Black, Barton, and Clyde Rivers. Each at Newport flows into Lake Memphremagog, ultimately by the St. Lawrence River reaching the ocean.

The eastern area in Essex County is drained by a large number of rapid streams flowing in a southeasterly direction into the Connecticut. Of these the Nulhegan is the best representative. Plate XVIII represents Barnet Falls at Barnet, Vermont.

The Passumpsic River on the south receives from the east Moose River and from the west Sleeper River then flows almost due south through a deep valley of incision bearing the same name into the Connecticut, thence into the Atlantic by Long Island Sound. Plate XIX represents Passumpsic Falls showing dip of schists to the east. Plate XX represents the Passumpsic Valley looking south below St. Johnsbury. Plate XXII represents Sleeper River Falls in Washington limestone, St. Johnsbury.

The western area furnishes the head waters of the Lamoille River which flows northwesterly through a deep valley cut through the pre-Cambrian schists and Green Mountain gneiss,

PLATE XIX.

Passumpsic Falls showing high dip of Phyllite Schist to the East, Passumpsic, Vt.

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PLATE XX.

Passumpsic Valley looking south below St. Johnsbury, Vt.

across the axis of the Green Mountains into Lake Champlain; thence through Richelieu River into the St. Lawrence.

TOPOGRAPHY.

The area traversed lies between parallels 44° 15' and 45° north latitude, and longitude 71° 30' and 72° 30' west from Greenwich. It comprises an area of nearly 3,000 square miles. Its valleys are both longitudinal and transverse — true valleys of incision. A beautiful illustration of such longitudinal valleys can be found in Woodbury extending along the Gulf Road south from Hardwick, directly west of Woodbury Mountain; the other to the north of Hardwick along the line of the erosional unconformity between the Lower Trenton limestone and the pre-Cambrian schists. The Lamoille River flows to the northwest from Hardwick through a transverse valley cutting across the axis of the Green Mountains. Burke Mountain and Wheelock Mountain in the north may mark somewhat the altitude of an old peneplane and are therefore measuring rods of erosion not unlike Mt. Ascutney in Windsor and Mt. Monadnock in southwestern New Hampshire. Most certainly there is a suggestive similarity in the altitude of these four mountains as found in the table of altitudes in a subsequent portion of this report. Prof. W. M. Davis of Harvard makes the Schooly peneplane the highest in New England representing an altitude of 1,800 feet which is approximately the altitude of the crest of the great anticline that traverses the center of the Waits River limestone.

The limestone being less resistant to the atmospheric agencies than the staurolites of Wheelock, Stannard, and Cabot, affords the deepest valleys. One limestone valley lies to the east of the Green Mountain axis and parallel with it, while another lies to the west of the pre-Cambrian terranes on the east. Its general topography might be suggested by a series of anticlines and synclines with a northeast trend in which the valleys are the synclinal troughs and the hills the anticlinal arches. The stratigraphical section, Plate XVII, gives abundant evidence of this undulation.

ALTITUDES.

An interesting and instructive series of altitudes has been observed not only along the lines of the railroads but upon mountain crests. Those along the railroads show variations in topography as affecting passenger and freight traffic. The following list has been arranged for the Montpelier & Wells River, and the St. Johnsbury & Lake Champlain Railroads from east to west; Boston & Maine, and Maine Central Railroads from the southern point within the area to the northern terminus within the State.

MONTPELIER AND WELLS RIVER RAILROAD.

Wells River	435
Boltonville	624
South Ryegate	724
Groton	773
Groton Pond	1094
Marshfield	1140
Plainfield	752
Montpelier	484

ST. JOHNSBURY AND LAKE CHAMPLAIN RAILROAD.

Lunenburg	844
East Concord	876
Miles Pond	1016
North Concord	1091
West Concord	876
East St. Johnsbury	786
St. Johnsbury	557
Danville	1341
West Danville	1496
Walden	1656
Dow	1411
Greensboro	1146
East Hardwick	1031
Hardwick	861
Wolcott	690

PLATE XXI.

Passumpsic Rapids flowing over the edges of closely folded schists, Barnet, Vt.

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BOSTON & MAINE RAILROAD, PASSUMPSIC DIVISION NORTH FROM WELLS RIVER.

Wells River	435
Ryegate	464
McIndoes Falls	441
Barnet	452
St. Johnsbury	557
Lyndonville	727
Barton	945
Newport	688
Derby Line	1042

MAINE CENTRAL RAILROAD.

Guildhall	874
Beecher's Falls	1093

GRAND TRUNK RAILROAD WITH A SINGLE OBSERVATION AT

Island Pond	1178

OTHER ALTITUDES.

Canaan	1053
Leach Pond	1760
Big Averill	1963
Little Averill	2093
Salem Mountain, limestone	1275
Salem Mountain, granite	1410
Willoughby Lake	1062
Willoughby Mountain	2654
Round Top, Victory	2200
Miles Mountain, Concord	2470
Blodgett Mountain, Stannard	2500
Wheelock Mountain, Wheelock	3000
Burke Mountain, Burke	3277
Ascutney, Windsor	3220
Monadnock, Jefferson, N. H	3181

GLACIATION.

Glaciation is a potent factor in the topography of the area, therefore it falls within the scope of the present report. The subject has been so thoroughly discussed by Prof. C. H. Hitchcock in the Fourth Report of the Vermont State Geologist 1903-04, that I will only briefly consider the matter. The depth of the ice mantle as it moved down from the Laurentide Hills must have been 5,000 feet, for the five highest mountains of Vermont, all over 4,000 feet, are glaciated to their very summits.

In October, 1897, in company with Dr. Hitchcock, the author spent some time in collecting Lower Trenton graptolites at Castle Brook, Magog, Quebec, and in quest of glacial evidences on Mt. Orford.

We did not content ourselves with the study of the mere foothills of this classic mountain. From the southwest side we ascended to the very summit, and within ten feet of the highest point we found a fine bowlder of Laurentian gneiss. A section of this erratic was sent to Prof. F. D. Adams, of McGill University, and this eminent authority was satisfied that the wanderer was Laurentian gneiss from the north side of the St. Lawrence.

I left Prof. Hitchcock at the flagstaff and went down quite a distance on the north side of the mountain, and at all altitudes found bowlders of metamorphosed sediments and irruptives, which argue in favor of the glaciation of Mt. Orford.

In the summer of 1904 I visited Owls Head finding kindred evidences of glaciation to its very summit. I have also found erratics of Laurentian gneiss in Vermont, fifty miles below the International Boundary at altitudes of over 2,000 feet amidst quartz veins beautifully polished and striated.

No principle of glacial geology seems more firmly established than that erratics pass from lower to higher altitudes. Dr. Bell states specifically in his "Glacial Phenomena in Canada" in Vol. I, Bulletin of the Geological Society of America, that Laurentian bowlders were transported from the comparative low region north of the Georgian Bay to tablelands of much higher altitudes. Tyrrell in his "*Glaciation of North Central Canada,*" Vol. VI of the Journal of Geology brings out the same facts.

The author has camped upon many mountains in Vermont

PLATE XXII.

Sleeper River Falls, St. Johnsbury, Vt.

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and most of the highest peaks in New Hampshire. Abundant evidence that these crests were ice covered exists upon them all. Therefore not a nunatak remained in all New England save Mt. Katadin, the majestic sentinel of Maine, due to the natural thinning out of the ice sheet towards its edges. The ice that overrode all the mountains of Vermont and New Hampshire, even the dignified Washington with height of 6,293 feet, came therefore from the low region to the north.

The general trend of the ice was southeasterly. Its direction may be traced not only by the striae upon rocks stoutly resisting disintegration and erosion but by erratics.

Another striking illustration is the large bowlder of peculiar concretionary granite transported over Wheelock Mountain from the village of Craftsbury, now standing sentinel in a door yard one mile below South Wheelock. The longitudinal and transverse valleys have both been deepened and broadened, outlets of valleys obstructed, and numerous placid lakes remain. A mantle of debris therefore covers the entire field save here and there on the stoss side where the preglacial soil has all been removed. A local terminal morain crosses the State in a westerly trend in the neighborhood of Lyndon and St. Johnsbury. The high terraces of the Passumpsic valley rising hundreds of feet above the river bed at Lyndon Center and St. Johnsbury give some evidence of the vast amount of morainic material thus deposited at this temporary lower limit of the ice and modified by the flooded rivers. Another section impeding progress in field work is in Concord and Lunenburg where the pre-Cambrian terranes are completely covered with a mantle of erratics. Around Lake Memphremagog where the planes of bedding and cleavage coincide and the rock is less highly metamorphosed, the mantle of glacial debris obscures the rock masses and thereby may prevent the discovery of the true diagnostic features of age.

LAKES.

The chapter upon topography would be incomplete without some reference to the scenic beauty and economic significance of numerous lakes. Scarcely a town exists within the area that is not studded here and there with these placid, transparent sheets of water. Mention will be made of only a few of those that have become important summer resorts thus bringing a certain amount of trade within the borders of the State, or perhaps more important than all, have become an inexhaustible source of power. Their origin is glacial. The valleys have been deepened by the scouring action of the ice. The original outlets of many valleys of incision were filled with glacial debris and the small outlets sought new channels.

ORLEANS COUNTY.

Lake Memphremagog at an altitude of 686 feet extends from Newport, Vermont, to Magog, Province of Quebec, a distance of thirty miles. It is estimated to cover an area of 48,000 acres of which 9,600 are in Vermont. Its scenery is unsurpassed in beauty. Its highest wall is Owl's Head, rising 2,749 feet above the lake, about two miles north of the lake on the western shore. Its bed is one of limestone and of slate. Practically it lies upon Lower Trenton and Devonian limestones. The former pass under the lake in its southern portion while the latter are found at Owls Hea d on the west, and Georgeville, Province of Quebec, on the east. A band of Lower Trenton slate interstratified somewhat with the lime falls between the two limestones.

Willoughby Lake in Westmore, six miles east of Barton, at an altitude of 1,c62 feet is unsurpassed in grandeur by any waters of New England, even if by Alpine lakes. Mural precipices rise 1,592 feet above it upon either side. From the crest of Willoughby Mountain 2,654 feet in altitude, it seems to stretch itself in the cardinal direction of north and south, a distance of seven miles. Although it looks like a narrow line it averages nearly a mile in width and covers about 3,840 acres. Its bed is in Waits River limestone. The origin is three fold. The limestone in Devonian times was broken through by granites upon either side of the lake. The crests of Willoughby Mountain on the east and Mt. Hor on the west stoutly resisted Mesozoic denudation while the intervening limestone easily suffered

PLATE XXIII.

Migrating Sand Dune near St. Johnsbury Center.

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solution. It was attacked both by the carbon dioxide of the atmosphere and the sulphuric acid formed in the oxidation of pyrites encased in both sedimentary and intrusive rocks. Upon the invasion of Vermont by the great ice sheet that spread over all of New England its lower portions filled with gravers tools found an easy channel which it immediately began to deepen. The stouter igneous material more easily resisted the ever planing action of these lower layers of ice, while the friable limestones readily gave way to its influence. A considerable pile of glacial debris, now somewhat modified drift, crosses the valley to the south and prevents the flow of its transparent waters into the Passumpsic River. A modified drift traverses the broader valley to the north which contains the outlet of the lake. Thus disintegration, solution, abrasion, and gravel building, has each aided in giving Willoughby Lake a depth exceeding 500 feet. Soundings have been made at 450 feet striking bottom but at the greater depth the bottom was not reached. Unexpectedly the shallow portions of the lake are without bowlders. In water of considerable depth the floor is seen covered with a fine white sand, resulting from the disintegration of the granite, showing perfectly uniform ripple marks as if made by the action of tides on the Atlantic Coast.

Barton Lake, in the village of Barton River, skirts the Boston & Maine Railroad for three miles and covers an area of 800 acres.

Derby Lake in Derby, although much smaller, covering only about 75 acres, is scarcely less beautiful.

Caspian Lake at an altitude of about 1,750 feet, lies in a bed of limestone. It is situated two and one half miles north of Greensboro Bend in Greensboro and about a three minutes walk from the village. It is impossible to see this lake, covering 2,780 acres, until you stand almost at the water's edge. There are few if any lakes that surpass it in its scenic beauty.

ESSEX COUNTY.

Nestled among the granite hills of the extreme northeastern corner of Vermont are found three lakes. Unlike the five lakes mentioned in Orleans County whose beds are limestone, these are in granite. Their shores are whitened by the granite sands from the disintegration of the surrounding wall rocks. These grains of sand are rounded and polished by the impact of the water. The lakes, surrounded by forests, are thus hidden from view until one comes upon them unexpectedly in the thickets. They are situated on the height of land, whence the waters drain on one side into the St. Lawrence through the Coaticook and St. Francis rivers, and on the other into the Connecticut river through Leach stream, the outlet of the smallest of these bodies of water. Leach pond covers an area of 114 acres at an altitude of 1,800 feet. Big Averill covers an area of 860 acres at an altitude of 1,963 feet. Little Averill covers an area of 1,280 acres at an altitude of 2,093 feet. The divide between the first and second is 2,013 feet and between the second and third 2,150 feet. A ten minutes walk only is required to reach Big Averill from Leach pond while Little Averill lies one mile to the southwest beyond Big Averill. The close proximity of these three lakes to each other, the low divides between them, and their access from the first by trail through the thicket are suggestive and interesting.

Another pond whose bed is in part granite and in part metamorphic schist is found in Concord. It is known as Miles pond lying at the foothills of Miles mountain at an altitude of 1,010 feet.

CALEDONIA COUNTY.

Caledonia County is not without its scenic lakes and ponds. Long Pond in Groton at an altitude of 1,050 feet, covers 2,500 acres. Like the lakes of Essex County its bed is granite. Although there are outcrops of Washington limestone lying near it on the east, there is no positive evidence that the limestone cuts beneath the pond. The area is still largely wooded and the lake furnishes the power for a large lumber industry.

Harvey's Lake in Barnet is 800 feet above sea level. Although it contains no more than 600 acres, yet it is one of the prettiest sheets of water in New England. Its bed is in Waits

PLATE XXIV.

Lowell Mountain from Irasburg, Vt.

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River limestone while intrusives of granite lie both to the east and to the west of it thus enhancing its beauty.

Another significant lake is St. Joseph's Lake in Danville and Cabot. It lies in limestone at an altitude of 1,490 feet. The limestone has a slight dip of only 10 to 15 degrees to the west. It must have been formed by the scouring action of the ice together with the greater solubility of that portion of the limestone forming its bed; or by the burying of the original channel of Joe's Brook, which is its outlet, by glacial debris. The present outlet of the lake falls 140 feet in a distance of 1500 feet over sheets of Waits River limestone, thereby furnishing most excellent water power both for cutting lumber and granite.

GEOLOGY.

To unravel the intricate details of the geological structure and diagram the true stratigraphical sequence of these heterogeneous terranes is no easy task. Hon. James Richardson found in 1872 that epidotic, chloritic, and serpentinous rocks with crystalline limestone and magnetites were characteristic of Upper Paleozoic as well as Lower Paleozoic terranes in British Columbia, the Eastern Townships, and New England. The geologist in the field fully realizes the possibility of error amidst these crumpled, folded, faulted, metamorphic rocks. There will exist considerable doubt and uncertainty until some geologist in his good fortune finds the true diagnostic feature in paleontological evidence within the State.

A.

PRE-CAMBRIAN.

This term as here used signifies a group of sedimentary rocks flanking the Waits River limestone on the west, and a lithologically similar group of sedimentary, or meta sedimentary, highly metamorphic rocks on the east.

The western member consisting of chlorite schists, micaceous quartzites, and gneisses, and flanking the Green Mountains on the east has been quite definitely settled as pre-Cambrian. It is this belt that carries the Eden and Lowell serpentine and asbestos deposits. No attempt has been made to determine its structural features save on the border of the limestones. The stratigraphical section is carried from Hardwick toward Wolcott, a distance of six miles until the rock assumes a westerly dip.

The eastern belt lies directly west of the Connecticut River. It stretches across Essex, Caledonia, Orange and Windsor Counties. It reaches a breadth of five to ten miles in Essex County and south of Wells River becomes a narrow band. Occasionally beds of talc and steatite are found within it.
Plate XXIV. Lowell Mountain from Irasburg.

a. Lunenburg Schist.

Lunenburg Schist is the chief pre-Cambrian representative in the eastern belt. Through this the Connecticut River has cut its sinuous channel along the interstate boundary. It is a highly metamorphic, green, greasy, chlorite schist often studded with pyrite. The chloritic phase comprises a belt two miles wide on the eastern slope of the cliffs from Guildhall to Hartland. A most excellent development can be found in Concord and Waterford. Sericites and occasionally phyllites are present in Barnet and Ryegate. At McIndoes Falls the dip of the sericite schist is 85 W. while in Barnet it is slightly to the east. Near the railroad cut below Barnet there is a small area with nearly horizontal position—a purely local character. Plate XXV represents a railroad cut in Lunenburg schist at Wells River.

b. Protogene Gneiss.

The eastern border of the Lunenburg schist is cut by several outcrops of protogene gneiss. Some of these cliffs rise 200 feet above the Connecticut River where with almost vertical faces they closely resemble the basaltic palisaides of the Hudson. Plate XXVI Barnet Cliff 100 rods along.

PLATE XXV.

Railway Cut in Lunenburg Schist, Wells River, Vt.

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PLATE XXVI.

Barnet Cliff, Barnet, Vt.

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c. Sheared Quartzite.

Flanking the Lunenburg schist in the west is a narrow belt of sheared quartzite. Two miles northwest from Lower Waterford on the farm of R. W. Remick this phase can be easily seen. Small veins of galena slowly increasing in width and number with descent are found in this member. It is represented in the section as lying above the chloritic schist as in a tightly folded synclinal trough. Its western dip is nearly vertical where it comes in contact with sheared diorite porphyra. A highly quartzose phase appears in Ryegate. When the detailed mapping of Essex County can be taken up, its field relations will be better understood.

Although no fossils have been found in the Lunenburgh schist and in this quartzite in the areas of the least metamorphism yet I am inclined to believe that their true stratigraphical position will be Cambrian.

d. Hornblende schist.

Hornblende Schist is often associated with the sericite. Sometimes it reaches a thickness of 1,000 feet. It often becomes feldspathic and can be catalogued a gneiss. Exact duplicates of specimens of gneiss from Baltimore, Maryland, are easily obtained along the Connecticut River in Orange County where it lies between the gneiss and the Lunenburg schist. The best representative in the northern field is in Barnet. Plate XXVII represents the cleavage plane dip in the hornblende schist in the cliff near East Barnet.

e. Metamorphic Feldspathic Schists.

There is a belt of considerable width in Concord and Waterford of a greenish, feldspathic schistose rock. It has been suggested by Dr. Mathews of Johns Hopkins University that it is a sheared amygdaloid. Every stage of gradation between a diorite porphyra and this highly metamorphic material can be traced in the field, but whether it represents an original feldspathic mica schist, an amygdaloid, or a diorite porphyra, only a large number of microscopical slides can determine. The phenocrysts of feldspar have suffered much decomposition and further study is necessary to determine its exact nature.

Prof. Hitchcock suggested in *Geological sections crossing New Hampshire and Vermont*, the term Montalban as equivalent of the White Mountain series in New Hampshire whose age is designated as upper Laurentian. In this report I have included these with the Lunenburg schist as pre-Cambrian awaiting further field investigation.

Dr. T. Sterry Hunt in 1870 suggested the same name, Montalban, for the terranes now known as the Waits River limestone and the Bradford schist. As the name has been applied to formations separated so widely by degree of metamorphism as well as by age the name is dropped from the present discussion. Some of the important dips in the pre-Cambrian terranes are here catalogued. Metamorphic schist, Concord, St. N. 40° E, dip 80° E.; Waterford, dip 85° E. Sheared Quartzite, dip 90°. In Lower Waterford, Lunenburg schist St. N. 45° E. dip 80° E. One mile west of Concord dip 80° W. Thus the whole series is everywhere tilted to a very high angle closely folded into anticlines and synclines.

B.

IRASBURG CONGLOMERATE.

Irasburg Conglomerate is so named from the town of Irasburg in Orleans County where it is best represented. The author in the summer of 1904 discovered this conglomerate on the farm of F. A. Willey one half mile below the village of Irasburg on the West Albany road, and visited it again in 1906. The fine exposure is on the left hand side of the road.

Its conglomerate nature is unmistakable. Pebbles of granite are tightly held in the folds of the highly metamorphic micaceous portion. One of these is six inches long and four inches wide. Fragments of diorites, highly metamorphosed schists,

PLATE XXVII.

Hornblende Schist with nearly vertical dip, East Barnet, Vt.

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and quartz pebbles, are also present in large numbers and the bands of limestone are interbedded with the more micaceous portions.

The structure of the conglomerate strikingly suggests a rapidly sinking sea upon whose shores these calcareous sands were deposited. As the beds of lime are siliceous and lithologically identical with the Waits River limestone it should both mark the basal member of the Lower Trenton series and the great erosional unconformity on the west. The shore was to the west from whence these pebbles came. It would be a distance of more than fifty miles in a southerly direction to kindred irruptives in the pre-Cambrian terranes to the east of the Waits River limestone. Furthermore the pebbles of granite and its associates are directly traceable to the kindred irruptives in the pre-Cambrian terranes in the west which are separated from the Waits River limestone by an erosional unconformity.

The history then is marked, (1). by a period of deposition in which many thousands of feet of sediments were laid down. The source of the material was the disintegrated portions of the Green Mountains to the west. (2). A period of rise during which these sediments were somewhat folded and brought above the sea level. (3). The introduction of igneous activities when the granite and diorites were intruded into the schists and along their lines of contact added new minerals. (4). A long period of denudation whose time of duration is most difficult to estimate. (5). A period of subsidence upon the margin of whose sinking floor these calcareous sediments were deposited then gradually in deeper, clearer, and more quiet waters the Waits River limestone was formed. (6). A period of rise in which the conglomerate was brought above sea level. (7). The introduction of intrusives into the limestone. (8). The present period of disintegration and erosion.

The general dip is to the west and the strike in a northeasterly direction. Strikes and dips can be taken in many directions owing to the highly folded and crumpled character of the formation. Some fifty rods from this outcrop toward Irasburg the conglomerate appears in much longer exposures on both sides of the brook where once there seemed to stand an old mill. Here samples of good limestone free from pebbles can be easily obtained. Dr. Hitchcock has described a bed of talcose conglomerate in Newport and Coventry, also at Owls Head, Canada, everywhere dipping under the bright green talcose schists apparently with scarcely any planes of stratification. This is flanked on the east by a slate then a limestone that Dr. Hitchcock would call Devonian, and then Montpelier slate.

The stratigraphical position of the Irasburg conglomerate is therefore capable of two interpretations. (1). That it is the basal member of the Waits River limestone formed upon the rapidly subsiding sea floor when the sea transgressed upon the pre-Cambrian schists. (2). That it is the basal member of a younger series of rocks lying in a narrow belt between the Montpelier slate on the east and the pre-Cambrian schists on the west. Comparison of specimens collected in the section crossed would lead one to accept at the present writing the former opinion. Further detailed field investigation is required before this most valuable diagnostic feature can be definitely translated.

Erratics of another coarse conglomerate were found to the east of the Bradford schist in Concord. The pebbles were much flattened by the intense pressure to which they had been subjected and often elongated parallels with the planes of foliation. S. R. Hall in his report relating to geology of northern Vermont, cites such a coarse conglomerate in Granby, Victory, and Concord. Although Hall recognized a similarity between the two, yet to me they are strikingly different. The former conglomerate is decidedly calcareous. The latter is devoid of lime. The former is micaceous and unquestionably sedimentary; the latter is micaceous and meta-granitic. As the former represents the shore line between the Waits River limestone and the pre-Cambrian schists on the west, so the conglomerate on the east may represent the shore line between the Bradford schist and the pre-Cambrian terranes on the east. The removal of the lime for a distance of five to eight miles may explain its utter absence from the latter conglomerate. It is possible then that these two conglomerates mark the border of the great trough in which the Waits River limestone was formed. In the absence of an opportunity to study this conglomerate in situ and in its field relations, I have simply called attention to another diagnostic problem demanding further investigation.

C.

DEVONIAN.

This brief discussion of a possible Devonian problem may or may not fall within the scope of the present report. The rock lies just outside the field of special investigation yet crossed in my recent reconnaissance. Dr. Edward Hitchcock calls attention to a narrow belt of limestone and slate flanking the pre-Cambrian schists on the east of the Green Mountain axis, and extending from Owls Head on the west shore of Lake Memphremagog as far south as Montpelier, Vermont. A thickness of 200 feet is accorded to the limestone in Coventry. It is characterized as a black, carbonaceous, slaty limestone ringing under the blow of the hammer. It has the normal strike of the terranes of northeastern Vermont, and dips invariably to the west, which position can only be explained by a fault or an overthrust.

At Owls Head, a few miles north of the International Boundary, Devonian fossils are beautifully preserved. A careful examination of the character of this formation was made in 1904 in hope of finding it represented within or bordering the Washington limestone, but Devonian fossils were not found in Vermont either east or west of the Lower Trenton slate. A kindred deposit is also found at Georgeville, Province of Quebec, which was likewise examined. An area of thickly wooded glacial drift intervenes between the exposure at Owls Head and Newport, therefore there is great difficulty in proving the continuity of the formation, the planes of cleavage coincide with the apparent planes of bedding. Strange indeed that in a contiguous area where metamorphism is no greater there should be no evidence of fossilization in Newport.

This apparent absence of Devonian characters may be indicative of Lower Trenton age and that the band of limestone is simply a narrow belt of Waits River limestone interstratified with Montpelier slate, which phenomenon is often observed on a smaller scale both at Newport and in Orange County. However, its exact relation is one of the problems that I hope to settle in my next terse report upon Orleans County.

D.

WASHINGTON LIMESTONE.*

This name the author applied in 1895 to the calcareous member of the calciferous mica schist of previous reports by Prof. C. H. Hitchcock, although the first publication of this term appeared in 1898. The name Washington was chosen because in that town in Orange County the limestone assumes its maximum typical development. Here it is that the strata lie in nearly horizontal position; the texture is uniform, the percentage of lime higher, and the polish which it receives finer than in any other part of the State. It was here also that the discovery was made in 1893 that the rock was sufficiently pure to be used as a marble. In 1898 more than twenty-five quarries had been opened and the demand was in excess of the capacity of sheds, polishers, and the capital invested, to meet the supply. Many of these quarries have been abandoned not from an inferior quality of the stone for monumental and structural purposes, but from poor financial management of the initial movers.

The limestone stretches itself across the entire State from north to south just east of the central line through Northfield and Montpelier. It approximates forty miles in width in Canada where it lies between the east and west division of the Quebec Group. In Hartford it divides by the intervention of the Bradford schist. The western member terminates in Cavendish in Windsor County. The eastern member crosses Windsor and Windham Counties

* In this paper the name Washington Limestone has been changed to Waits River Limestone. See note at the end.

PLATE XXVIII.

Limestone interstratified with Slate, Newport, Vt.

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and may be the formation in Massachusetts known as the Conway schist.

Three distinct phases of the limestone can be easily recognized in the field. The first is a beautifully banded variety closely resembling the Columbian marble of Rutland, Vermont. The typical development of this variegated variety is found at Waits River, Vermont, where it was quarried in 1897-99 by W. M. Carnes and Company, and advertised as "Vermont Imperial Variegated Granite." This banded phase crops out again in Danville and in Westmore. Small, yellowish brown crystals of phlogopite are scattered through it with orientation parallel with the planes of bedding. At the foot of the cliff at the base of Mt. Hor in Westmore this feature is well illustrated. Here the strata lie in a nearly horizontal position though dipping at a few degrees to the west.

The second phase is a dark steel gray silicious limestone sometimes banded in appearance but more often fairly uniform in color. The darkest and purest portions of this variety are found in Washington and in Danville. In Washington large blocks can be secured perfectly uniform in color without seam or flaw, and in Danville it presents the same aspects though in a less marked degree. In the village of Danville by the roadside leading to the station is a typical outcrop of this variety. In Derby and Newport it becomes much lighter in color, and in Canada a very light gray in many localities. On the east it becomes a lighter gray and passes into the Waits River phase. On the west the rock holds its fairly uniform texture as can be seen in Craftsbury, Hardwick and Walden. This variety is susceptible of the highest polish and takes a lettering legible to a greater distance than any other known rock. This is especially true when the face of the letters with their polished surfaces stand out in bold relief from the white hammered background.

The third phase is a dark carbonaceous variety of more shaly texture and never susceptible of a fine polish. It graduates by almost insensible gradations into the dark steel gray variety yet in many cases there is quite a rapid transition from one to the other. This variety is the uppermost member, for it flanks the steel gray variety upon the east and the west. On the east in St. Johnsbury along the Boston and Maine Railroad below the village beautiful illustrations of the dark variety can be observed and on the west in Albany, Irasburg, and Newport. This phase assumes a more nearly vertical position until it is intimately interstratified with slates and shales that overlie the Washington limestone. Plate XXVIII represents such interstratification at Newport.

A few special phases, apparently local in character, are worthy of recognition. One of these is about one mile south of South Walden Post Office where the rock becomes very arenaceous with great fissility along vertical planes and in which there are some suggestions of fossils. It is an area demanding further investigation along that line.

A second localization presents itself in Irasburg about one mile east of the village on the road to Glover. Here the limestone assumes a dark brown color, nearly a vertical position and becomes more shaly than at any other point investigated. Here also fractured portions of the fragile limestone seem to imitate organic forms. The locality may well be marked as one worthy of further search for diagnostic features.

At a third locality it is entirely different in type and character. It is located in Westmore on the south side of Willoughby Lake. It is the brecciated phase of the Waits River limestone —purely local in effect. Such limestone breccias were not supposed to exist on the east of the Green Mountain axis and the discovery in Westmore is attended with no little interest. Many fragments were found at the base of the perpendicular cliffs. The fragments of the dark gray limestone are sharp and angular, showing no appearance of the rounding processes. These are cemented together by crystals of pure white and yellowish-white calcite. The source of the lime is from the shattered limestone rock. The fracturing was done by the numerous intrusives cutting their way through the limestone. These will be noticed later as bosses and stocks of granite, dikes of diabase of the camptonite order, and amygdaloids.

The Waits River limestone as a unit is interstratified with

PLATE XXIX.

Easterly Dip of Limestone near St. Johnsbury, Vt.

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numerous beds of phyllite schist. Daley says in his Geology of Mt. Ascutney, "The limestone is in the phyllite series." The converse in reality is true for the limestone predominates in the areas described. The interstratified phyllite often becomes black and plumbaginous from the graphite disseminated through it. This is well illustrated at the John Guyer quarry on Observatory Knob, St. Johnsbury.

A single hand specimen shows distinctly thirteen faults in the graphitic phyllite schist. In the same vicinity it often becomes ottrelitic from hexagonal scales of ottrellite set transverse to the planes of foliation. This often becomes so tough and compact that it is catalogued as hornblende. This mineral has developed in the limestone in many places, perhaps best observed in Barnet. Staurolites, and incipient iron garnets are common in the bands of phyllite.

The limestone underlies the Bradford schist which will be described in E, the next division of this report. On the east through Barnet, Burke, and St. Johnsbury its inferior position is distinctly noticeable. At St. Johnsbury on Observatory Knob its easterly dip is clearly seen at an angle of 45 degrees. Plate XXIX.

In Danville there are three distinct cuts made in the Waits River limestone by the St. Johnsbury and Lake Champlain Railroad. The first of these is known as Badger Gap 300 feet long and estimated 40 feet high. Here the limestone lies with a low dip of 15 degrees to the east. The strike is normal to the area, N. 30 E. The strata is cut with numerous quartz veins, highly folded, sometimes parallel with the bedding, often crossing the bedding planes at all angles.

The second is known as Crane Ledge about one mile east of Danville. It is 600 feet long and reaches a maximum depth of twenty feet. The sheets are nearly horizontal, practically the crest of one great anticline yet there are many apparent foldings in the limestone. One interesting feature within the cut is the presence of an intrusive. A dike of camptonite varying from three to five feet crosses it in a northwesterly direction. It is somewhat concretionary in its decomposition and presents most beautiful slickensides.

The third cut is a few rods east of West Danville. It is not as large as the other two but marks the western slope of the anticline.

Plate XXX shows the nearly horizontal position of the strata.

This anticline which is so well represented in Danville traverses the entire limestone formation. Its position in Washington is equally well represented. In Marshfield and Peacham it is broken through by a large mass of granite, so that upon the east in Peacham the rock dips to the east and on the west in Marshfield the rock assumes the westerly position. This northeasterly trend carries the anticline through Sutton where good exposures of the limestone can be observed. Nearer the International Boundary it is broken through again by irruptives especially by the large granitic area in Holland and Norton. In general a synclinal fold can be traced between the anticline and the Montpelier slate on the west. The coincidence of the planes of cleavage and the planes of bedding would lead to the conclusion that the cleavage was developed prior to the folding. The arenaceous character of the limestone would indicate an Ordovician sea of some considerable depth. The fine grains of silica may have come from the disintegration of sandstone of Cambrian age and unconsolidated sands of even later age. The lime was largely derived from organic remains yet in part it may have been the results of chemical precipitation.

The presence of the beds of phyllite so often interstratified with the lime may represent varying conditions either in the sea or on adjacent land masses whereby the finer and more clayey material was laid down with the calcareous sand. The continental uplift which brought northeastern Vermont above the sea level and caused the deposition of sediments to cease occurred at the end of the Ordovician.

E.

BRADFORD SCHIST.

This name was used by the writer in 1898 to designate the non-calcareous member of the calciferous of mica schist Prof. Hitch-

PLATE XXX

Horizontal position of Limestone, West Danville, Vt.

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cock. Bradford was chosen for several reasons. It is the most important town in Orange County bordering the Connecticut River. The rock exposures are easy of access to all geologists visiting the area. This is especially true in following up the Waits River Valley to Cassville. Here the schist reaches its typical development. The breadth of the exposure is about seven miles; the schists are highly folded and contorted. To the south it grades into a micaceous quartzite with perfect parallelism of the scales of mica between the layers of silica. In many instances it becomes gneissoid in appearance, to the north it is finer grained often phyllitic and ottrelitic. The fine grained nature of the northern portion is nowhere better illustrated than in St. Johnsbury ,east of the Passumpsic River and west of East St. Johnsbury.

The name Bradford schist includes all the non-calcareous members of the old "Calciferous mica schist." It embraces therefore the quartzite, staurolitic, actinolitic, amphibolitic, ottrelitic, graphitic, and garnetiferous phases lying between two large narrow belts of slate and shale, one on the east near the Connecticut River, the other on the west passing through Newport and Montpelier to Barnard.

The average strike of the belt is practically parallel with that of the Washington limestone N 10° E in the southern portion, N 20° E in the central, N 40° E in the northern. The dip is at a very high angle, either east or west and the whole series of schists suggest complex and intricate folding into anticlinal arches and synclinal troughs. On the brow of the hill to the west of East St. Johnsbury many of these anticlines can be seen and some have been photographed. Like Appalachian foldings the western slope of the anticlines are everywhere the steeper of the two. These sharp folds are suggested in the diagramatic structural section accompanying this report. The planes of superinduced cleavage are not always coincident with the planes of deposition. Sometimes the variation will be marked by only a few degrees as on the southeast side of Kirby Mountain, while occasionally they are nearly at right angles with each other.

The Bradford schist alone was supposed to represent about one half the thickness of the "Calciferous mica schist" which Dr. Hitchcock has represented as 12,000 feet. The depth of 6,000 feet appears by the complex folding to be too large an estimate. It often makes its appearance overlying the Waits River limestone in bands only a few hundred feet in thickness and small narrow bands in unmapable area are interstratified with the arenaceous limestone.

Some of the different phases of the schist demand special consideration. In the northern portion on the east it graduates by almost insensible gradations through shaly material into the Waterford slate, so that no sharp line of demarcation would suggest an unconformity between the two. On Observatory Knob, one half mile west of St. Johnsbury, there seems to be a very peculiar relation between the Waits River limestone and the Bradford schist. The former in a quite unexpected manner grows poorer and poorer in its lime contents until the uppermost portions become entirely free from lime, and the phyllites predominate. This transition by imperceptible gradation from a siliceous limestone well suited for structural purposes to a phyllite schist with sufficient rift and grain for flagging stone have been observed in the same quarry face, I think only by Dr. W. J. Miller, of Hamilton College, in the Piedmont region of Maryland. The fact that the stone and phyllites dip 35°-45° E is suggestive that the two were laid down in conformity with each other, and that the subsequent superinduced cleavage is at an angle not far removed from 45 degrees with the planes of bedding.

If the crest of the hill alone be examined one would catalog the area from topography as Bradford schist; from the lower altitudes he would plot the area as Waits River limestone. But every quarry however small that has been opened upon the higher altitudes shows this gradational feature with descent from the lime impoverished schist into the typical limestone of the area involved. Whether the continued working of the Guyer quarry for building purposes will throw additional light upon the problem is an open question. The problem most certainly is suggestive.

One mile to the east the nature of the schist has entirely changed. It has become graphitized and the dips are at high angles. There is a suggestion of a possible fault along the incisional valley of the Passumpsic between the Waits River limestone and the Bradford schist which is here shown to be the younger member.

Another phase of the Bradford schist is well represented in a dumb bell shaped area of considerable dimension in Marshfield, Cabot, Walden, Stannard, Wheelock. It is five miles wide both to the north and south while in Walden it nearly disappears. The belt is highly staurolitic. Nearly all exposures are thickly studded with magnificent cruciform twins so beautifully penetrating each other that the impassioned collector is discontented with a mere specimen of regulation size. This is especially true in Cabot on the crest of the hills to the west of St. Joseph's Lake where the staurolitic schist lies in a gentle synclinal fold with the low dip of five degrees to the west, and in the road bed passing over Wheelock Mountain from Stannard to South Wheelock.

It is to this member so stoutly resisting both disintegration and erosion that the remarkably higher altitudes of Wheelock and Stannard are due. Wheelock Mountain maintains an altitude of sufficient proportion for a signal to be seen off the Atlantic Coast, although the mountain is 150 miles inland and nearly fifty miles west of the White Mountains. Such a signal was there planted in the eighties under the direction of Prof. Charles H. Pattee.

Another unusual and remarkably interesting phase of the Bradford schist is found in Barton about two miles east of the village near the road to Westmore. The exposure here somewhat suggests a gneiss but it very closely resembles a minette, the difference being not in the large black scales of biotite but in the ground mass. The hand specimen may be catalogued a biotite schist with perfect parallelism of the black scaly mica. A microscopical section is necessary in order to determine how feldspathic the material is. The section is not noted for its size but for its striking peculiarity. It is cut through by large masses of exceedingly dark biotite granite. The introduction of this intrusive has had much to do with the high degree of metamorphism of this peculiar member; in fact the preponderance of biotite in the granite suggests that this biotite schist has suffered sufficient fusion to cause its transition into a black biotite granite.

An arenaceous phase of the Bradford schist is found in Marshfield. In fact it is strikingly suggestive of a micaceous quartzite, in which the mica in small scales has carefully arranged itself with perfect parallelism, and the fine grains of quartz were originally granules of fine gray sand. About two miles east of Marshfield village this arenaceous variety has been largely used for whetstones. They are free from small garnets; they possess a clear grit and do not gum. Several other localities exist in northeastern Vermont where this local use of the arenaceous phase is apparent.

Other phases of the Bradford schist might be described, but cannot be discussed in the present report.

These various phases of the Bradford schist not only suggest different degrees of metamorphism but different conditions of the sea at the time of their original deposition. The whole suggests a rising continent toward the close of Lower Trenton time. The coarser material seems to have been laid down in reasonably close proximity to an old shore line. The drainage of contiguous areas was fairly rapid so that coarse sediments were transported into the Ordovician sea and with checked velocity deposited the sediments. The finer sediments were carried out into deeper water and therefore laid down further away from the shore. The sea was the more shallow toward the south and deepened quite rapidly toward the north, for the southern portion carries the coarser material and the northern portions the finer. A striking difference in the character of these oceanic sediments can be observed by comparing the Bradford schist in Cassville four miles from Bradford up the Waits River Valley with that at East St. Johnsbury along the Moose River Valley.

The continental rise may have been temporarily arrested and in fact slight subsidence introduced to allow for the deposition of the finely triturated clays whose metamorphic representatives now appear in the two belts of clay slate flanking on the east the Bradford schist and on the west the Washington limestone.

F.

MONTPELIER SLATE.

The following terms, Montpelier slate, Northfield slate, and Montpelier and Northfield slate, have been used interchangeably and indiscriminately in the various reports on the geology of Vermont. If there has been any discrimination whatever, "Northfield slate" has been used more in a commercial sense than in the designation of a geological formation.

I would propose therefore the single term Montpelier slate for the terrane that has been formerly discussed under these different names. The name Montpelier is chosen for several reasons. It is the capital of the State and no other geological formation has received the adjective Montpelier in its description. It is in Montpelier that the slate is the most easy of access for all who wish to study its characteristics. Here it has reached its greatest breadth and highest development. Here it is, scarcely outside the city limits, if at all, on the farm of Charles T. Sabin that it has been extensively quarried for roofing purposes.

The name Montpelier then is here applied for the first time in a purely geological sense to the belt of slate that flanks the pre-Cambrian schist to the east of the Green Mountain axis, lying conformably upon and often interstratified with the Waits River limestone. Its southern terminus is in Barnard, Vermont, from thence it extends intermittently through Northfield and Montpelier, Irasburg and Newport into Canada on the north.

The entire series is a highly metamorphic rock derived from beds of plastic clay. Its perfect cleavage is the direct result of molecular rearrangement through heat and pressure, whereby the mineral grains are flattened and rotated into planes parallel to each other. These planes may or may not coincide with the planes of original deposition of the clays. In Northfield there is a striking difference between the two, the cleavage being at a high angle while the planes of bedding are at a low angle to the west. In the northern areas the two planes seem to coincide. This is especially true in Canada, where in a contiguous area the diagnostic fossil graptolites are most beautifully preserved.

The black color of the Montpelier slate is due to fine carbonaceous particles disseminated through it. The color and texture is quite uniform, although in the more southern portions of this narrow belt the slate assumes a bluish black hue and a finer texture, while in the north it becomes a jet black and sometimes approaches a carbonaceous shale. This latter feature is very distinct on the west of the Black River in Albany.

This slate differs somewhat from the Waterford slate which is discussed in the next section of this report. It is darker and more uniform in color, less laminated in structure, and freer from all secondary minerals. Therefore it is better suited for roofing purposes, blackboards, sinks, stationary washtubs, etc.

The general trend of the strike is at first north and south, then it changes in Northfield to N 30 ° E and from thence maintains the same general direction to Lake Memphremagog. The slate in the southern portion stands in nearly a vertical position. In Albany it dips 65 ° W, in Newport 80 ° W.

Although this belt of slate has been often mapped as passing through Wolcott, I am confident that it was a generalization, for a detailed section running from Hardwick to Wolcott, the last six miles of which was over pre-Cambrian terranes, revealed no slate whatever, only 660 feet separates the last outcrop of the limestone from the first of the pre-Cambrian schists. The slate is not embodied in the structural section because in the neighborhood of Hardwick it seems to have been either squeezed out entirely or have suffered sufficient denudation for its complete removal. From Albany the slate can be traced with considerable definiteness, in spite of the morainic material mantling the area, to Lake Memphremagog; and from thence across the lake into Canada, where its fossiliferous nature is well shown.

The contiguous land areas were approaching base level and therefore yielded their constituents to sedimentation the more slowly. The waters receiving the sediments were comparatively quiet, thus allowing the deposition of the finest clays and muds. The grand continental uplift that brought the northeastern section above sea level occurred at the close of the Ordivician, and the oceanic connection with the Gulf of St. Lawrence was closed.

G.

WATERFORD SLATE.

The introduction of the term Waterford slate, as it is new in geological literature, demands an explanation. It is here used to locate a narrow belt of slate that may or may not be the equivalent of the Montpelier slate already described.

This terrane flanks the Bradford schist on the east, and is separated from the pre-Cambrian metamorphic series by a fault. Lithologically it is a slate graduating into a fine grained phyllite of the Bradford series to the west. In Waterford it reaches its maximum thickness, 400 feet of workable slate. It extends northward through Concord, Kirby, and Burke, where it seems to terminate although detailed field work in the unexplored granitic area to the north may reveal outcropings of the slate still nearer the International Boundary.

Its strike in Waterford is N 10° E, dip 80° to 85° E, with apparent planes of bedding nearly coincident with those of cleavage. The slate appears in many towns bordering the Connecticut River as far south as Guildford. Presumably it is all Waterford slate. Occasionally as in Bradford the slate has been squeezed out entirely or has been removed by erosion so that the slate is not a continuous belt from Burke Mountain in the north to Guildford in the south. The strike varies from N 45° E in Norwich to N 10° E in Waterford and the dip from 60° W in Hartford to 80° E in Waterford.

In general the slate is a dark gray compact tough laminated rock often studded with incipient staurolites, occasionally with iron pyrites. In Thetford it becomes soft and extremely fissile, and assumes a bluish black hue. Several localities from time to time have yielded small quantities of the slate for economic purposes, cemetery work, flagging, underpinning, roofing, and road material.

The Waterford Slate Company in 1855 spent several thousand dollars in developing the quarry on Waterford Mountain two miles south of East St. Johnsbury on the St. Johnsbury and

Lake Champlain Railroad. In 1860 it is reported to have been sold to Webster and Keys of Concord, New Hampshire, for $7,777. They became involved in litigation and a foreclosure ensued. There seems to be no reason why the quarry should not be worked at good profit with modern machinery and modern methods. I have split with a single blow of a trimming hammer samples three feet long and from two feet thick to the thickness of one quarter of an inch. The grout around the old quarry exposed for half a century shows how stoutly the slate will resist disintegration. A seventy five foot front can be easily obtained with excellent opportunity for grout beds.

A peculiar wall-like rock suggestive of a basaltic dike about ten feet in thickness stands directly in front of the face of the quarry. It is a compact, highly metamorphic mica schist consisting essentially of quartz and brown mica. Its peculiar feature is the pebbles of quartz and the small crystals of some secondary mineral that demands microscopical investigation. It suggests in some ways a basal conglomerate. If it is such, then an erosional unconformity exists between the slate and the highly metamorphic series to the east. Bosses of granite appear in the slate both on Waterford Mountain and in Kirby. The Waterford slate has also been quarried in Fairlee, Thetford, and Guildford, but not to large extent even though the quarries are near the Passumpsic Railroad.

The condition of the adjoining land areas yielding the sediments and the character of the waters in which they were laid down were not materially different from those involved in the discussion of the Montpelier slate therefore they need not be introduced anew.

H.

IRRUPTIVES.

a. Granites.

The term granite in this discussion is used in a geological rather than a commercial sense. It excludes the gneisses in which a certain parallelism of some accessory constituent has been developed in the rock mass, usually of sufficient importance to be recognized even in the hand specimen. It includes the heterogeneous series of holocrystalline irruptives whose essential constituents are quartz and some acid feldspar, generally orthoclase, and some accessory mineral either mica, or hornblende, or both.

Scarcely a town exists amongst the fifty two towns under consideration that has not suffered the introduction of these acid intrusives. That these granites are not the residual backbone of mountains formed from sedimentary deposits by complex folding is perfectly plain, for they have developed many new minerals through contact metamorphism. One of the best illustrations of this phenomenon is the large crystals of calcite along the zone of contact between the granite and the Washington limestone through which it was irrupted. Their surface exposures are often tarnished with the oxides of iron resulting from the decomposition through oxidation of pyrites. Even in many such localities as soon as the sap rock has been removed excellent building material, permanent in color, is obtained.

There is a considerable difference in the texture of the granites in northeastern Vermont, even among those belonging to the same irruptive period. In general the more southern areas are the finer grained though there are some striking exceptions to this rule.

The Knox Mountain granite in Orange is much coarser than the Kirby granite on Kirby Mountain, while the Barre granite is distinctly finer than the high grade granite of Graniteville, Province of Quebec, just north of the International Boundary.

A few of the areas that have produced large commercial outputs or are fully capable of doing so with the expenditure of a limited amount of capital to open up the industry are worthy of careful consideration. The Barre granite that has been so ably discussed by G. I. Finlay in the third report of the State geologist on the "Mineral industries and geology of certain areas" needs no further comment, save by way of comparison of analysis.

The next field of importance although lying in the extreme northern part of Washington County is found on Woodbury

Mountain. While this area has been discussed somewhat in the past, new facts have been brought to light that have never been published. The author first visited this area with Prof. Hitchcock in 1895 when I measured blocks one hundred feet long and seven feet deep without seam or flaw. It is doubtful if a larger shaft can be obtained at any quarry in the world than upon this mountain.

The Woodbury Granite Company is one of the largest and best in equipment of any kindred company in the United States if not in the world. Through the kindness of Mr. George H. Bickford, its manager and the president of the Hardwick and Woodbury Railroad, I have had many excellent opportunities of carefully examining both the quarries on Woodbury Mountain and the processes used in the manufacture of the stone. The granite is situated six miles south of the village of Hardwick and is reached by a railroad owned and operated by the Woodbury Granite Company.

The quarries are situated upon the brow of the mountain where a 300 foot working face is easily obtained. The adjacent valleys furnish an excellent site for the disposal of the grout for the mountain is a residue of erosion and nearly surrounded with deep incisional valleys in the Waits River limestone. The quarry is entirely open cut work and the stone is not surpassed by any in durability, permanency of color, beauty when polished, ease of working, and seldom in resistance to compression. Its remarkable freedom from all accessory injurious constitutents renders it a special favorite for such constructions as the pedestal of the Sherman monument in Washington, the new Pennsylvania State House at Harrisburg, and the Rock Island Railroad Station at Chicago.

Inasmuch as the granite on the crest of the mountain owned and operated by the E. R. Fletcher Company possesses the same general characteristics and in fact is the same main stock it seems advisable before taking up the analysis to note the work of the company. Whatever the Woodbury Granite Company quarries can yield, the Fletcher quarries can duplicate save the height of the working face and the ease of working the stone.

No town in Vermont or the United States is more dependent upon its granite industry than Hardwick. Without it, the thriving village would cease to exist as such and only a few dwellings would mark the site of the present prosperous town. Twelve hundred men are employed in the industry. The monthly payroll of the two Companies exceeds $50,000 and the annual output of granite $1,250,000. Four-fifths of this comes from the Woodbury granite alone.

While the town of Bethel in Windsor County lies entirely outside the area of this report, I beg leave to call attention to the only known granite of its kind. Not on account of its striking peculiarities, but because its chemical analysis is available for comparison and because it is in part owned and operated by the Woodbury Granite Company and worked both at Bethel and Hardwick. The Ellis Company, of Northfield, also operates the same general stock, cutting the stone at their large sheds in Northfield, rather than in Bethel.

The striking peculiarity of the Bethel granite is the utter absence of a pigment in its essential constituents, the paucity of accessory minerals, and its unexpected compression strength. With only a few dark blotches occasioned by scales of mica it assumes a whiter appearance than any known granite, in fact whiter than nearly all marbles, even the yellow waxy luster of the Italian prototype of our own Vermont statuary marble. It can be cut and carved with readiness into any form to serve human desire. When polished these dark blotches become more prominent but they are scarcely noticeable upon the hammered surface. I have compared a five inch cube of this granite with hammered faces, with the interior of buildings painted with lead carbonate and with zinc oxide and found the Bethel granite to be the whitest of the three. For the construction of massive buildings of permanent white color the stone is without a peer.

Through the interest of Mr. G. H. Bickford I am able to present here a copy of the chemical analysis and compression tests made at the Watertown Arsenal, Massachusetts.

Chemical analysis of the Woodbury gray granite, quarried by the Woodbury Granite Company, Woodbury, Vermont.

Silica	SiO_2	70.75
Oxides of iron	Fe_2O_3 FeO	2.70
Aluminum	Al_2O_3	15.80
Lime	CaO	2.03
Magnesia	MgO	1.35
Soda	Na_2O	3.88
Potash	K_2O	3.46
Loss at red heat	H_2O	.35
		100.32

Correct,

(Signed) E. K. MacNutt.

(Signed) F. E. Hobbs,

Major, Ord. Dept., U. S. A.,

Commanding.

Chemical analysis of Hardwick white granite, quarried by the Woodbury Granite Company at Bethel, Vermont.

Silica	SiO_2	72.70
Oxides of iron	Fe_2O_3 FeO	Trace
Alumina	Al_2O_3	18.35
Lime	CaO	2.80
Soda	Na_2O	4.52
Potash	K_2O	.95
Loss at red heat	H_2O	.60
		99.92

Correct,

(Signed) E. K. MacNutt,

(Signed) F. E. Hobbs,

Major, Ord. Dept., U. S. A.

Commanding.

In introducing for comparison an analysis of the dark granite from Millstone Hill in Barre, made by G. I. Finlay, given on pages 55 and 56 of the State Report, 1901-02, I find a strikingly close resemblance in the three granites.

	Barre.	Bethel.	Woodbury.
SiO_2	69.89	72.70	70.75
Al_2O_3	15.08	18.35	15.80
Fe_2O_3 / FeO	2.50	Trace	2.70
MgO	.66	——	1.35
CaO	2.07	2.80	2.03
Na_2O	4.73	4.52	3.88
K_2O	4.29	.95	3.46
H_2O at 110 and ignition	.54	.60	.35
P_2O_5	——	——	Trace
	99.76	99.92	100.32

By comparison of these analyses it will be seen that the Bethel granite is the most acid, the Barre the most basic, the Woodbury granite intermediate between the two; that the soda-feldspar, albite, predominates in the Bethel stock almost to the exclusion of the potash feldspar, not only found so abundantly in the Barre and Woodbury granite but the common feldspar of our New England granites, and that the oxides of iron are practically absent from the Bethel stock while present in the others. This can be explained by the paucity of the scales of mica which being complex silicate of aluminum, magnesium and iron would yield the oxides of iron in their chemical analysis. Another interesting comparison can be made in the compression tests of the Bethel and Woodbury granites. These tests, like the chemical analyses, were also made at Watertown Arsenal, Massachusetts, by which the vastly superior strength of the Bethel stone will at once become apparent.

Test No. 13,261.

Woodbury Gray Granite, quarried by the Woodbury Granite Company, at Woodbury, Vermont.

First crack.	Ultimate strength. Total.	Ultimate strength. Per o inches
Pounds.	Pounds.	Pounds.
199,000	203,500	22,460
181,000	181,000	19,850
168,000	184,000	20,110
Pyramidal fractures, Average,		20,806.

Correct,
J. E. Howard.

F. E. Hobbs,
Major, Ord. Dept., U. S. A.,
Commanding.

Test No. 13,261.

Hardwick white granite, quarried by Woodbury Granite Company, at Bethel, Vermont.

First crack.	Ultimate strength Total.	Ultimate strength Per o inches
Pounds.	Pounds.	Pounds.
287,000	307,000	33,120
301,000	318,400	34,350
272,000	388,900	31,990
Pyramidal fractures, Average,		33,153

Correct,
J. E. Howard,

F. E. Hobbs,
Major, Ord. Dept., U. S. A.,
Commanding.

PLATE XXXI.

Granite Quarry on Kirby Mountain.

A few compression tests of well known granites will show the strength of the Vermont stone and its suitability for structural purposes:

	Strength per Square Inch.
Hornblende granite, Bay of Fundy	11.916
Biotite granite, New London, Connecticut	13.338
Biotite granite, Westerly, Rhode Island	16.077
Biotite granite, Vinal Haven, Maine	16.770
Hornblende granite, Quincy, Massachusetts	16.750
Biotite granite, Barre, Vermont	19.560
Biotite granite, Woodbury, Vermont	20.806
Biotite granite, Milford, Massachusetts	22.610
Hornblende granite, St. Cloud, Minnesota	28.800
White granite, Bethel, Vermont	33.153

The Bethel granite shows a strength in resistance to compression more than twice that of the beautiful Westerly, Rhode Island, stone and vastly superior to that of any other known granite. Special attention should also be called to the fine light granite of the Northern Granite Company of Hardwick. The granite is in Hardwick rather than in Woodbury and from it more than fifty fine statuettes have been cut. The same company operates the quarries at Mackville one mile east of Hardwick village. A considerable quantity of granite is also found on Buffalo Mountain to the west of Hardwick. This latter intrusive is not in the Washington limestone but in the pre-Cambrian terranes.

The next field of importance is in Kirby about five miles north of West Concord, not so much from the annual output and the number of men employed as from the striking resemblance of the stone to Barre granite and its universal application. Several quarries have been opened within the past two years. One of these is shown in Plate XXXI, where the length and thickness of the upper beds can be readily seen. This photograph was taken at the new quarry of the Burke Granite Company. The photograph does not do justice in any way to the quarry. Last summer the author found a large area uncovered and sheets many times thicker and larger than can be hauled down the mountain side ready for quarrying.

The work is under the management of Joseph Welch who will open another large quarry this summer to the north of the one represented in Plate XXXI. A part of this stone is cut at West Concord, part at St. Johnsbury, and a part shipped to local cutters elsewhere.

A word might be offered in respect to the properties of Mr. Kearney as they are not included in what is commercially known as Burke Mountain Granite. In June, 1905, Mr. Kearney had several quarry sites opened up ready for sale of stock or quarrying. The granite lies on either side of the road leading to the quarries of the Burke Granite Company on Kirby Mountain. A small brook runs between the places now uncovered as quarry sites. There exists also an easy disposal of grout. The granite is of good grain, even texture, comparatively free from iron and black knots. Like other granite around Kirby Mountain it is susceptible of a fine polish. It affords an excellent opportunity for investment, for the stone is unlimited in supply, and situated only four miles from West Concord, where it finds a ready market, selling in the rough at sixty cents per cubic foot.

The granite of Blue Mountain is a dark biotite granite susceptible of a fine polish and extensively used. The pay-roll for cutters alone is $350 per diem.

In Groton a large mass of fine grained biotite granite has been irrupted in the Washington limestone. The stone seems to be growing in favor each year for both monumental and structural purposes. The largest quarry is situated just south of the village of Groton from which more than 2,000,000 cubic feet of stone have already been taken.

About thirty years ago a granite site was discovered and a quarry opened in Derby, Vermont. For a quarter of a century it met only a local demand. The permanency of the stone was reassured by recent inspection of shafts and monuments so long ago removed from the quarry. About four years ago the Newport Granite Company was formed with offices in Newport, Vermont, and Albany, New York, under the presidency of A. A. Flint,

PLATE XXXII.

Fig 1.
Feldspar Crystal, Cabot, Vt.

Fig 2
Craftsbury Granite.

and the quarry management of George Farquharson. The supply of this stone like that in so many other localities is inexhaustible and like the other high grade granites it lies in the Washington limestone. For permanency and evenness of color the stone is not surpassed by any quarry in New England. As the output has been estimated by Mr. Farquharson as $90,000 for 1906, we may expect even a much larger and more profitable industry in the future.

At West Danville there lies the possibility of another large granite industry. St. Joseph's Lake as already noted elsewhere is four miles long and one mile wide. At its outlet where the granite sheds are situated, the available water power can scarcely be surpassed. Many excellent quarries can be opened up within five miles of the lake. The best of these is in Peacham about four miles southwest from West Danville.

In Cabot just at the head of St. Joseph's Lake there is a very peculiar pinkish white and tough granite on the farm of Asa B. Mack. It is noted for its close resemblance in certain localities to the famous cassiterite bearing greissen of Cornwall, England, and in hand samples to lepidolite.

The feldspar has been largely replaced by quartz, and biotite is entirely absent. The scales of mica are white or pink and exceedingly small. The feldspar when present may be albite. In fact it is so fine in many sections that a microscopic slide would be necessary to determine its nature.

Associated with this fine grained variety are some exceedingly coarse phases. It carries crystals of feldspar that have assumed large proportions. A single crystal of albite, the sodium feldspar, exceeds four feet in length and two feet in thickness. Plate XXXII, Fig. I, represents a fragment of such a crystal lying by the roadside. In this albite there are intergrowths of orthoclase, the potassium feldspar. The cleavage of this mineral is so highly perfect that many fine hones have been fashioned from it.

On Miles Mountain to the north of Miles Pond can be found hundreds of acres of good quarry land. Two distinct varieties of granite can be obtained, one light, the other exceedingly dark, in fact it may be designated black granite. In the former variety the mica is biotite and the orthoclase a pure opaque white. This property is largely owned by W. L. Hastings of Miles Pond. I. H. Brown has several acres of granite lying within one mile of the railroad in sheets with perfect ritt and cleavage. The stone ought to be worked with good profit. The black variety is one of the handsomest granites ever seen in Vermont.

It has often been said that no red granites exist in Vermont. Perhaps they do not in considerable quantity. The largest exposure known in the State is in Newark about fifteen miles from West Burke, ten miles from Island Pond, and on land owned by Charles E. Silsby of West Burke. A long ledge of granite is here exposed to view, sometimes rising 185 feet with vertical face, and a 400 foot working face could be easily obtained. It is in this ledge that in 1905 I found Vermont's red granite. The rock is strikingly suggestive of famous Scotch granite of Peterhead, and may well be used in place of it. The feldspar in part is red and in part white. It is susceptible of a fine polish and so far as can now be ascertained permanent in color.

The red variety has been reported from the west side of the mountain also. Its distance from any railroad is the one great difficulty in way of the rapid development of a good industry in Newark.

Another granite demanding more than a passing notice is found in Craftsbury just east of the village. It has found its way into more museums than any other granite of the State. It is noted not for its economic uses but for its peculiar orbicular structure. Large concretions of biotites are thickly scattered through the rock mass; so suggestive are they of fossil fruits that they have been catalogued "petrified butternuts." Plate XXXII, Figure 2, represents the black face of such an orbicular granite. This peculiar granite has been reported in much smaller areas as far north as Stanstead, Province of Quebec, and as far south as Northfield. Erratics have been transported many miles by the ice in a southeasterly direction even over Wheelock to South Wheelock already noted elsewhere. The granite has been thoroughly discussed by Dr. E. Hitchcock on pp. 563-565, Vol. II, Geology of Vermont, 1861. Kindred varieties have been found in Rhode Island, North Carolina, Finland, Sweden and Sardinia.

Space forbids the mention of scores of other localities where granite is found in northeastern Vermont, and in several instances where it is worked at the present time as in Irasburg, Salem and Norton, but the detailed mapping of the area I trust will bring all of these to the attention of the general public.

b. Gneiss.

Gneiss differs from granite only in the parallelism of its accessory mineral which may be either mica, or hornblende, or both. The commercial world scarcely recognizes the distinction. Parallelism may not be detected in hand samples but be apparent in the quarry face so that the curator of a museum would catalogue his sample granite, while the geologist in the field would label it gneiss. In fact by insensible gradation the one passes into the other.

Like granites gneiss may be developed either from the metamorphism of sedimentary rocks through heat and pressure or from igneous masses. The origin of the gneiss in northeastern Vermont is doubtless the latter. One area flanks the Connecticut River in Maidstone and Guildhall and appears also in Waterford. Before it can be accurately discussed it needs further study. It may be the same as the large area of gneiss around Bellows Falls.

A second locality entirely different in color and character of the quartz is found in Concord, one mile north of North Concord. It is a highly metamorphosed and contorted rock, dark gray in color, with its scales of biotite arranged in perfectly parallel layers. How far this belt of gneiss can be traced to the north is unknown.

c. Dikes.

The intrusives of northeastern Vermont are numerous and sometimes cover large areas. They range from the strongly acid pegmatites to the strongly basic diabase. When the term pegmatite is considered in its older sense, namely that of a graphic granite, it finds a most excellent representative in Westmore at the foot of the perpendicular cliffs of Mt. Hor. Here the true graphic character is well established. The quartz is quite abundant, and closely resembles the arrowhead characters of Assyrian inscriptions, while the crystals of feldspar are large and perthitic. It may have been intruded in connection with the closing phases of igneous activity. Time forbade the study of its relation to intrusives of the earlier stages.

When the term pegmatite is considered in the light of the later years as applied to coarse veins of granite with large crystals of feldspars and micas predominating, many occurrences are found in nearly every town. They traverse the preceding formations in all directions. Their detailed study presents a very interesting problem.

Diorites.—These granitoid rocks are more numerous in the older pre-Cambrian series than in the Ordovician. They range from the normal diorites, consisting essentially of plagioclase and hornblende, to the quartz-mica diorites. The former variety is far in excess of the latter and is well distributed throughout the eastern area. The latter finds a peculiar and intensely interesting rock mass that needs further study in the vicinity of Miles Pond. The mica is brown biotite and the hornblende is both brown and green. The ground mass is highly altered and the rock weathers with a peculiar pitted surface.

Gabbros.—Gabbros are very numerous within the area. Some of these are fine grained granitoid rocks as in Barnet while others are extremely coarse as in the second railroad cut below East Barnet where it is sixty-six feet wide and extends several miles in a northeasterly direction strikingly suggestive of a batholith.

Diorite Porphyra.—A considerable area of this igneous rock is found in Essex County cutting the highly metamorphic pre-Cambrian schists. The green color and bladed structure of the hornblende suggests a secondary origin, while the phenocrysts of feldspar are greatly decomposed.

Diabase.—Dikes of diabase are common both in the highly

PLATE XXXIII.

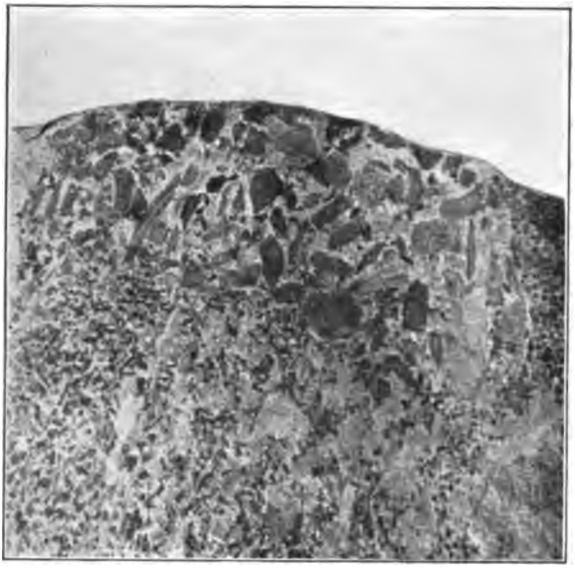

Fig 1.
Brecciated eruptives cemented together by granite, Concord, Vt.

Fig 2.
Veins of granite in a porphyritic diorite, Lunenburg, Vt.

metamorphic and the limestone series. By their peculiar composition some of these suggest cord wood, others what is known as the onion structure, where they cut the limestone in a vertical position. Sometimes they run east and west, sometimes northwest and southeast but always at some angle with the strike.

Sometimes they are amygdaloidal and of the camptonite order, with large phenocrysts of hornblende. In Newark the augites are completely altered to chlorite and the feldspars much kaolinized.

Perhaps the most interesting of them all is the very handsome dike of amygdaloidal diabase in Westmore which cuts the Washington limestone and is completely studded with crystals of calcite.

Porphyrite.—Another basic igneous rock often appearing in the schists should at least be mentioned. It is so highly altered that little can be said without further study as to its original structure. The manganese and iron constituents are wholly altered and the typical feldspar unrecognizable. The white phenocrysts are set in a grayish and sometimes greenish background as at Boltonville.

To settle the age of these irruptives and their relation to each other will require further study. Some of the diorites and porphyries are younger than the granites. Plate XXXIII, Figure 2, shows a large number of granite veins penetrating a highly metamorphic diorite in Lunenburg. In Concord these more basic irruptives have been shattered in angular fragments and cemented together again by granite as seen in Plate XXXIII, Figure 1. Often large fragments of diorites and gabbros are found completely encased within the granite, therefore they must be younger. This, however, does not prove that there are no intrusives younger than the granite.

I.

CLAYS.

As I have already noted under the caption, Glaciation, the area considered in this report was subjected to an ice mantle in Pleistocene times. Beneath the ice and in its lowest portions various kinds of rock were ground to an impalpable powder which now consist of a hydrated silicate of aluminum bearing both mineral and organic impurities.

Scarcely a town exists in this northeastern section that is without its brick houses and its old brickyard. Inquiry has led in every instance to the definite statement that the bricks were manufactured from bowlder clay within the town. The comeliness of these dwellings testifies to the highly ornate character these home made brick now possess. While the most of these yards have been abandoned because timber was cheaper, yet a few remain and their products find a ready market. The largest of these is in East Ryegate owned and operated by Mr. M. H. Gibson. The brick are of a high grade and are shipped to the largest cities in New England.

Two small and less extensive plants are located at St. Johnsbury Center. These are operated by Alfred J. Rioux, who employs about a dozen men. The present capacity of the yards is 250,000 bricks worth from $6 to $7 per thousand, these are of permanent bright red color and have been shipped mostly to St. Johnsbury, Barton, Newport, Vermont, and Berlin, New Hampshire. The modified drift of the Connecticut, the Pasumpsic, and the Black River Valleys, furnish an abundance of high grade plastic clays well suited for structural purposes.

J.

PALAEONTOLOGY.

The discussion of this problem is so complete in the State Report for 1901-1902, pp. 94-99, that it seems inadvisable to take up the matter again in detail at this time. The author regrets that in the four years that have elapsed since the above report was issued no new light from the discovery of fossils can be thrown upon the problem. The Canadian area to the east of Lake Memphremagog, Lot XIX, Range II, has been visited with the observance of a goodly number of graphtolites in the black, clay slate that is lithologically identical with the Montpelier slate. If this belt of slate passes under Lake Memphremagog then it appears at Newport and should yield graphtolites. A diligent search around the lake will, I think, as soon as an opportunity presents itself, reveal these diagnostic features in Vermont.

A few more crinoidal stems have been found in Salem, on Salem Mountain, a few in Derby, and a few in St. Johnsbury, but their geological range is so great that they fail to throw new light on the problem. In samples the author has collected from Salem Mountain, Prof. C. H. Hitchcock thinks he sees some resemblance to fossil corals. In a fragment of the Irasburg conglomerate there is some evidence of a fragment of Favosites reticularis. It is a suggestion—I can say no more for it. In Westmore in the Waits River limestone there is also a suggestion of some species of Strophodonta. Although it may represent a cavity subsequently filled with pure calcite.

These evidences give no positive proof whatever and we are thus driven back to the contiguous Canadian areas for palæontological arguments and to lithological similarity of contiguous areas, to determine the true stratigraphical position of these heterogeneous terranes.

Accepting the Canadian diagnostic evidence as conclusive the uppermost members are Lower Trenton. This does not imply that the lower portions of the great body of Waits River limestone might not be older than Lower Trenton. Its formation may have begun early in the great Ordovician Sea, continued without unconformity, and ceased with the great continental uplift at the close of the Ordovician.

An attempt has been made to correlate this area with the Piedmont region in Maryland. The evidence is entirely in favor of a much younger series of rocks than those represented in the southern field. The distance of 550 miles from Baltimore is too great to allow lithological similarity much weight. While lithologically the Baltimore gneiss and the Setters quartzite with its stretched tourmalines may be duplicated, the Waits River limestone is devoid of the characteristic tremolites of the Cockeysville limestone. No evidence of fossils has yet been discovered in this southern field, while a few have been suggested in the northern area. No graptolitic slate or shale overlies either the Cockeysville limestone or the Wissahickon schist in the south, while in northeastern Vermont such a member seems to be present. If the Piedmont limestone is represented at all in this eastern section it may be in the lenses of limestone in Norwich and Lunenburg which most certainly are older than the Waits River limestone.

K.

PROBLEMS UNSOLVED.

The work that remains to be accomplished in northeastern Vermont is as follows:

(1). The careful field mapping of the entire area, which demands continued detailed field work. In this consideration Orleans County ranks first in importance, because of the possible diagnostic evidence in a fossil content in the less highly metamorphic section around Lake Memphremagog.

(2). The careful investigation of the extent and stratigraphical relation of the so called Devonian limestone flanking the pre-Cambrian schists to the west of the Waits River limestone.

(3). The extent and true significance of the Irasburg conglomerate, to settle the open question whether it forms the basal member of the Waits River limestone, or whether it is post-Waits River limestone and the basal conglomerate of the narrow belt of questioned Devonian.

(4). A most indefatigable search in the shales and slate around Lake Memphremagog for evidence of Lower Trenton graptolites that are so perfectly preserved in the shales at Castle Brook, Magog, Quebec. The brief time allowed for my reconnaissance has not permitted this much coveted investigation.

(5). The careful study of the numerous intrusive granites that have become a very potent factor in the commercial development of Vermont.

(6). The collection of all the irruptives in Essex County and the preparation of microscopical slides for petrographical study. This is necessary before many of these igneous rocks can be definitely named and their age determined. Many of these intrusives are so peculiar in character that they present a most important and intensely interesting problem.

(7). The study of the diorite porphyra, so well defined along the Moose River in Concord, to ascertain its relation to the metamorphic schists and sheared intrusives.

(8). The investigation of the fibrolite schist on Burke Mountain whose striking peculiarity is a large amount of fine sand disseminated through it in the form of magnetic iron.

(9). The extent of the gneissoid conglomerate in Granby and Victory and its relation to the Bradford schist.

(10). The nature and relation of the highly metamorphic Lunenburg schist catalogued in this report pre-Cambrian, as of old, with the confident prediction that it will ultimately fall in its true geological horizon Lower Paleozoic, probably Cambrian.

Note.—Since writing the above report the author has submitted to the Committee of Geologic Formation names at Washington, D. C., a list of names to be applied to the terranes of northeastern Vermont that might become permanent in Geological literature. Some of the names previously chosen and which appear in this report were found to be preoccupied. The final report of the committee was not received until it was too late to change the names in this present report. The sole object in the choice is to obtain uniformity with the work of the U. S. survey and thereby avoid duplication in formation names. The effect of this co-operation in preventing confusion must be decidedly beneficial.

The following names proposed by the writer have been unanimously adopted by this committee. Doubtless these names can be used in subsequent reports.

Lunenburg Schist as per report.
Waterford Slate as per report.
Irasburg Conglomerate as per report.
Waits River Limestone as per report.
Vershire Schist as a substitute for the Bradford Schist which name was pre-occupied; and Memphremagog Slate, for the Montpelier Slate which name was likewise pre-occupied.

C. H. RICHARDSON.

The following paper is a report by Mr. G. E. Edson, of St. Albans, upon his investigations in and about that place. For some years Mr. Edson has very diligently explored the area described and it is quite safe to say that no one else has collected anything like so complete a series of the local fossils or has so complete a knowledge of the geology of the region.

For two years past the author has been acting as field assistant and it is believed by the Geologist that the following pages will be found to contain much valuable information as to the fossiliferous beds of that portion of Franklin County which has been studied.

Inasmuch as such widely famous localities as the Parker Ledge and Highgate Sandrock are in the Cambrian as is also much of the territory investigated, Mr. Edson has prefaced his report by a history of the Cambrian, especially as far as this is connected with Vermont geology.

The paper consists therefore of Part I, HISTORICAL SKETCH OF THE CAMBRIAN AGE AS RELATED TO VERMONT GEOLOGY and Part II, THE GEOLOGY OF ST. ALBANS AND VICINITY.

Although Mr. Edson's first paper consists largely of matter that has been published elsewhere and is therefore a compilation, it presents in a concise form facts not easily within the reach of most of the residents of this State. It is also eminently fitting that such a historical sketch should appear in a Vermont Report.

PART I.

Historical Sketch Of the Cambrian Age as Related to Vermont Geology.

G. E. EDSON.

Under the title "Organic Remains in the Quartz Rock," in Vol. I, page 356 of the Report of the Geological Survey of Vermont, 1861, it states:

"Several species of fossils occur in the quartz rock. They are a species of Lingula, a mollusk resembling the *Modiolopsis*, a straight chambered shell, *Scolithus linearis* (Hall) and a few fucoids. * * * *

The Lingula is from the north part of the principal range of quartz rock in Starksboro, near Rockville, at the house of Mr. Hill. The locality was discovered by Henry Miles, of Monkton.

The "Modiolopsis" chambered shell and encrinal remains were found in hyaline quartz on the west side of Lake Dunmore."

In 1859, Noah Parker, a resident of the town of Georgia, Vermont, called the attention of the Rev. Zadock Thompson to fossils found in the shale on his farm, who sent them to Professor Hall, who in 1859 described them and referred them to the Hudson River shales, subsequently in 1860, this reference was changed to the Quebec group.

On page 367 of the above volume reference is made to "Fossils of the Georgia Shale." The following species of organic remains have been found in the Georgia slate in Vermont. *Barrandia Thompsoni*, (Hall) *B. Vermontana* (Hall), *Bathynotus holopyga*, (Hall), *Graptolithus Milesi* (Hall.) The trail of an annelid and unknown species of fucoids."

On page 372 of the same report, in giving description of *Graptolithus Milesi*, found in the Georgia shales, Prof. Hall says, "The specimen from which the figures of this species were derived, is part of a bowlder of Georgia slate, picked up in Monkton by Henry Miles. It was discovered almost twenty years ago, but had not been carefully examined before by any palæontologist.

The bowlder was probably derived from the Georgia slate, either in Georgia or St. Albans."

An appendix to Vol. 2 of this report named on page 942, under the head of "Some new or little known species of Lower Silurian fossils from the Potsdam Group (Primordial Zone) by E. Billings," a list of new species is given which contained many from the Straits of Belle Isle and a few from Vermont, that were discovered by the Rev. J. B. Perry and Dr. G. M. Hall. These gentlemen were engaged in making a careful geological examination of the rocks and fossils of their neighborhood. The following fossils were found one and a half miles east of Swanton: *Palaeophycus incipiens*, *Obolella cingulata*, *Paradoxides Vermontana* and *P. Thompsoni*; these fossils were found in the black slate, conformably interstratified with the sandstone and magnesian limestones, which constitute the principal mass of the formation. Mr. Billings noted the fact that the four above named species were the prevailing forms of that formation and as they are the most abundant in the limestones of the Straits of Belle Isle there can be little doubt that the two deposits although eight hundred and sixty miles distant from each other, are of the same age. He also says the occurrence of *Scolithus linearis*, and the general aspect of the fossils, also show that those rocks must be very nearly, if not exactly, in the same geological horizon with the Upper Primal sandstones and slates of Pennsylvania.

The brachiopods *Obolella cingulata*, *Orthisina festinata* and *Camerella antiquata* were also found at the Swanton locality by Dr. Hall and Rev. Mr. Perry.

In a foot note on page 948, of the 1861, Vermont Report, Mr. Billings says of the brachiopod *Obolella cingulata*, "I have examined many casts of the interior of this species and am inclined to the opinion that it is generically distinct from *Obolella chromatica*. * * * Should, upon further examination, my suspicions turn out to be well founded, I shall call the genus Koturgina, after the celebrated European naturalist Koturga."

Four new Trilobites were also found *Conocephalites Adamsi*, by Perry, Hall and Billings, in the Potsdam group about a mile and a half east of Highgate Springs.

Conocephalites teucer, in the Potsdam group at the Swanton locality by Perry, Hall and Sir W. E. Logan.

Conocephalites vulcanus, was found in the same beds as the *Conocephalites Adamsi*.

Conocephalites arenosus, was found by Mr. E. Billings in the thin-bedded sandstone by the side of the road leading from Moore's Corner in St. Armand to Saxe's Mills in Highgate, Vermont, about one mile south of the Province line. This sandstone was considered to be of the Potsdam group.

On page 950 of the Appendix of the Report, under the title "Crustacea," *Paradoxides Vermontana* was referred to as being found in the limestone of Anse au Loup, and that they seemed more abundant there than *Paradoxides Thompsoni*.

The genus here referred to as *Paradoxides Thompsoni* was first given the generic name of *Olenus* by Hall in 1859, who afterwards, in 1861, changed it to Barrandia. Emmons in 1860, and Barrande in 1861, used the generic name *Paradoxides*. A foot note on page 950 of the Vermont Report, 1861, referring to the generic name of this species is as follows: "In a postscript to the 14th Regent's Report, dated October, 1861, which I have seen in the form of a single loose sheet, Professor Hall proposes to change the generic name of these species to Olenellus. If the genus should turn out to be distinct from Paradoxides, I shall be most happy to adopt the name."

"On page 358, of the Vermont Report, reference is made to the series of rocks lying in the town of Georgia in Franklin

County. The name Georgia Group, or Georgia slate, is given to this group of rocks rather than to any other, such as Fair Haven slate or Castleton slate, because it is a purely geographical designation and has no reference to the economical value of the slate."

Two reasons may be given for the preference of Georgia.

1. The whole of the group is developed in the town of Georgia, but is not in either of the others mentioned.

It is a rule of geological nomenclature, that the whole series of rocks be developed in the town, mountain, or along the river from which the name is derived.

2. Nowhere but in Georgia, in Vermont, are the characteristic fossils of the group displayed. They have as yet been found only in the New York portion of the southern terrane.

The geological character of the group is best developed in Georgia and we are therefore compelled to use the name of this town in describing the slate geologically.

The Georgia slate includes all the following varieties of rock:

1. Clay slate.
2. Roofing slate.
3. Clay slate approximating to micaceous sandstone.
4. Various kinds of limestone.
5. Brecciated limestone.
6. Conglomerates composed of pebbles of limestone."

Although Dr. Emmons began the study of the Taconic area in Berkshire County, Mass., he extended his investigations into Bennington County, Vt., and to the west, into Washington County and Renssalaer County, New York, and as the Taconic system must include the Taconic area, which trends throughout Vermont on its western border, the "Georgia Group" must, consequently, represent a terrane under that system.

In the summer of 1844, Dr. Asa Fitch, discovered fossils in a black shale in Washington County, New York, which was referred by Emmons to the Taconic slate or "Argillite" of Eaton.

Dr. Fitch sent the fossils to Dr. Emmons, who described from them two species of trilobites, under the names of *Atops trilineatus* and *Elliptocephala asaphoides*.

These are the first two discovered species of the *Olenellus* fauna.

In the Vermont or Lake Champlain area, Prof. C. B. Adams, in 1845, described the occurrence of roofing slate in the south-western portion of Vermont, which he referred to the taconic slate of Emmons, without further attempt to assign them to a geological horizon.

In 1847, he mentions it in his studies of the " Red Sandrock " and noticed the discovery of fragments of trilobites, which Prof. Hall identified as *Conocephalus*. He assigned the " Red Sand rock " to the Upper Silurian, correlating it with the Medina sandstone.

Dr. Emmons corerlated the Red sandstone with the Potsdam sandstone and Calciferous sand rock, and considered it to be conformably superjacent to the Taconic slate at Snake Mountain and at Sharp Shins near Burlington, Vermont.

Sir William E. Logan, from the enclosed fossils discovered in the dark shale of the Georgia Group, assigned them to the upper part of the Hudson River Group, or a distinct group above the Hudson River Group.

In 1847, Prof. James Hall identified the shales of the Georgia Group, as belonging to the Hudson River Group or Lorraine shales.

In 1861, Mr. E. Billings noted the correlation of the " Red sand rock" with the Medina sandstone, and assigned them upon palaeontological evidence. to the Potsdam group. Mr. Billings, also corrected the statement of Professor Hall, that the trilobites of the Georgia slate were from the Hudson River terrane and referred them to the Primordial or Lower Potsdam, thus transferring them to the Cambrian formation.

In 1867, Prof. C. H. Hitchcock identified the Winooski marble of Vermont, with the Red sand-rock and stated that *Olenellus Thompsoni* occurred in the superjacent slaty layers. In a historical review of the rocks of Vermont, he referred the black slate, Georgia slate, Red sandrock and quartzite to the Potsdam group.

Prof. Jules Marcou studied the Georgia slate and the Red sand rock series in Northern Vermont. It is doubtful if he examined the typical Taconic area, and upon such examination referred the Georgia slate to the Taconic of Emmons and the Red sand rock to the Potsdam sandstone.

· So varied were the opinions of the different geologists who had studied the Taconic range in the State of Vermont that it became necessary to make a thorough investigation of the work included in the "Taconic System" and in that way if possible, give value to the name Taconic in American geology.

The American Journal of Science, Vol. XXXV, pp. 229-242, 1888, contains an article by Chas. D. Walcott, under the title, "The Taconic System of Emmons and the use of the name Taconic in Geologic nomenclature" from which the following abstracts are taken.

"The Taconic System of Dr. Emmons as it is developed in Berkshire County, Mass., was composed of five different rocks.

1. A coarse granular limestone of various colors which I have denominated Stockbridge limestone.

2. Granular quartz rock, generally fine-grained, in firm, tough, crystalline masses of a brown color, but sometimes white, granular and friable.

3. Slate which for distinction I have denominated Magnessian slate.

4. Sparry limestone, generally known as the sparry lime rock.

5. A Slate which I have named Taconic slate, and which is found at the western base of the Taconic range. It lies adjacent to the Lorraine or Hudson River shales, some varieties of which it resembles.

Dr Emmons founded the "Taconic System," under the belief that it was composed of older formations than those of the New York Lower Silurian, the base of which was the well known Potsdam sandstone. In the Memoir of 1842, he says; "But I have at the head of this section asserted that the slates and masses of the Taconic system are not related to, or connected with, those of the Champlain group. By this I mean that they are not the same rocks in another condition."

Again he says, "They are to be considered, however, as furnishing us with a knowledge of that state which immediately preceded the existence of organic beings." After further field study his views became more positive in regard to the relation of the Taconic to the Lower Silurian rocks. He says; "I shall take the broad and distinct ground that the Taconic System occupies a position inferior to the Champlain division of the New York system, or the Lower division of the Silurian system of Mr. Murchison."

In 1856 Dr. Emmons divided the "Taconic System" into an upper and a lower division, he called the "Granular Quartz" the basal member of the Paleozoic sediments on the North American Continent.

He describes its occurrence in Vermont and follows it, without interruption, across Massachusetts into the northeastern part of Dutchess County, New York, and also south into Putnam and Weschester Counties. The stratigraphic position was determined by its relation to the crystalline rock beneath and the superjacent strata, as no fossils were known by him from the formation.

He considered the "Lower Taconic" to be composed of three non-fossiliferous pre-Silurian formations—"Granular quartz, Stockbridge limestone and Talcose slates," that were unconformably superjacent to the crystalline gneisses beneath, and conformably subjacent to a great series of slate, forming the "Upper Taconic," that in turn were unconformably subjacent to the lowest of the Lower Silurian formation, the Potsdam sandstone.

Dr. Emmons correlated the "Taconic System" with the Cambrian system of Sedgwick, in his first memoir of 1842, in the following words: "The Taconic rocks appear to be equivalent to the Lower Cambrian of Professor Sedgwick, and are alone entitled to the consideration of belonging to this system, the upper portion being the lower part of the Silurian system."

In the year 1886 Charles D. Walcott of the United States Geological Survey, began field work on the so called "Taconic System," of Emmons. Previous to this time in the field season of 1883-4 he had studied the Upper Taconic strata of northern Vermont.

He found upon examination of the fossils alluded to in the "Geological Survey of Vermont," as being found on the west side of Lake Dunmore that the straight-chambered shell was a cast of *Hyalithes communis*, a Cambrian species. And that the Lingula of Starksboro near Rockville was *Nothozoe Vermontana*, also a Lower Cambrian species.

Prof. H. M. Seely of Middlebury College, who found in quartzite bowlders on the west side of Sunset Hill, near Lake Dunmore; *Nothozoe Vermontana* and a species of *Hyalithes* closely resembling *H. communis*, also the head of a species of trilobite undistinguishable from *Olenellus Thompsoni* of the Georgia formation in Franklin County, Vermont. He says "I visited the Lake Dunmore locality in company with Professor Seely, and found fossils in rounded quartz bowlders, but the quartz ledges in that vicinity gave no traces of them.

As all of these fossils had been found in quartz bowlders, which had been transported by water or other means to the locality where they were found and as a close examination of the rocks in that vicinity had revealed no fossils, they became of no value, or aid in solving the problem under consideration.

The Woodford locality was too indefinitely described to be found, but as transported bowlders afforded me *Nothozoe* and traces of trilobitic remains, similar bowlders were probably the source of the specimens mentioned. In Sunderland, east of Arlington, on Roaring Branch, *Scolithus* occurs abundantly in situ, in quartzite; and angular blocks of quartzite were found, one mile up the ravine, that contained *Hyalithes* and fragments of trilobites; but they were not traced to the beds from which they were derived. Two miles east of Bennington, however, success attended my search for fossils in situ. They occurred on the old Week's farm north of the old Windham turnpike, in light colored quartzite, the fossils consisting of *Nothozoe*, *Hyalithes* and *Olenellus*."

"As a result of the finding of these fossils in situ in the quartzite east of Bennington the fossiliferous bowlders are given value, as they were probably distributed through the valley to the west during Quartenary time and by the floods of the present time.

The quartzite was traced north into the valley of Roaring Branch, and it is a continuation of the deposit on the western slope of Bald Mountain , to the south it extends along the west side of the ridge leading to Dome Mountain, in Pownal, northeast of Williamstown, Mass. On the western summit of the mountain, towards Williamstown, the quartzite series come in unconformable contact with the pre-Cambrian gneiss, and fragments of trilobites, apparently the genus Olenellus, were found about one hundred feet above the contact.

It now became necessary to trace this fossiliferous horizon in the quartzite from Starksboro to Bennington, Vermont, and to Dutchess County, N. Y., where Dr. Mather considered the "quartzite" metamorphosed Potsdam sandstone and he so called the compact sandstone of Stissing Mountain in the northwestern part of Dutchess County, N. Y.

A careful examination of the sandstone locality of Stissing Mountain resulted in the finding of *Hyolithellus micans* in the imestone layers resting immediately on the sandstone and the heads of *Olenellus Thompsonii* in the sandstone, fifty feet or more below the limestone.

Hyolithellus micans is known only in the Georgia terrane of New York, Vermont and Canada.

The limestone and marble belt that outcrop both on the eastern and western side of the Taconic range, from palæontological evidence discovered by Messrs. Wing, Dana and Dwight had been referred to the sparry limestone or Upper Taconic by those writers who favored the view of the pre-Cambrian age of the Lower Taconic.

Prior to August 5th, 1887, determinable fossils had not been found in the limestone series east of the Taconic range.

At that date he found, in the eastern limestone, in the town of Pownal, Vermont, about half a mile north of the Massachusetts line, a number of fossils that were weathered out in relief on the surface of a compact, clouded marble. The collection gave *Enomphalus* (?) *Murchisonia bellicincta* and *Murchisonia Milleri*, a fauna that belongs to the Trenton terrane, and by it we can correlate the Eastern with the Western limestone.

"In September, 1887, I found fossils on both the eastern and western sides of Mt. Anthony on the line of strike of the Taconic range. On the west side the limestones dip eastward and are well exposed one mile south of the Hoosic N. Y. post office, About 400 feet of limestone are shown in this section and wear the upper part of it, shales appear. The shales are in their beds alternating with the limestones at first, and then they increase until the interbedded limestone disappears and the typical Taconic "talcose slates" of Emmons are the prevailing rock. In the limestone below the shales a stratum was found crowded with the shells of the genera Maclurea and Murchisonia, and to any one conversant with the Trenton-Chazy limestones of Washington County, N. Y., both the lithology and fossils of the Mt. Anthony limestone at this point, would prove the geologic horizon to be that of the Trenton-Chazy. Crossing the mountain to the eastern side, at a point three miles south of Bennington, Vt., abundant fragments of crinoids occur in a dark bituminous limestone, above a band of clouded marble. The crinoids seemed allied to *Homocrinus gracilis* of the Trenton limestone of New York.

Above the dark shale there is a band of arenaceous limestone upon which I noticed a fragment of an *Orthoceras*, an *Euomphalus*-like shell and section of what appeared to be a *Rhynchonella*. This limestone is lithologically similar to that conformably overlying a bed of marble that dips towards and passes beneath Mt. Anthony at a quarry two miles west of Bennington Center.

I next visited the north side of Graylock peak, a typical locality of Dr. Emmons'. The limestone and marbles are of the same lithologic character as those of Mt. Anthony with the exception of the bituminous limestone, carrying the crinoids. Only one fossil was found that could be recognized. It appears to be the inner whorl of a gasteropod related to *Euomphalus* or *Maclurea*."

"Having verified the stratigraphy as published by Dr. Emmons and Professor Dana, and having found Trenton-Chazy fossils in the marble belt, I crossed the Taconic range to its western base, in the town of Berlin, N. Y. This section is a repetition of the Graylock and Mt. Anthony section with the exception of less alleviation in the lower part of the shales and in the limestones. Continuing up the west slope of the mountain more or less impure limestones are met with in which I found *Solenopora compacta*, plates of crinoid columns, *Murchisonia gracilis*. (?)

The fossil-bearing limestone is subjacent to, and interbedded with, shales that are succeeded by arenaceous limestones which, in turn, are conformably subjacent to the shales and schists of the Taconic range.

The next locality examined was one described by Dr. Emmons as showing fossiliferous limestones of the Champlain series, resting unconformably upon the "Taconic schists." He studied the section, where it is very much broken and disturbed, and found evidence that sustained his view. If he had gone a mile to the north, he might have discovered that the shales pass unconformably beneath the limestone and also, that the shales occur conformably above it. Fossils were abundant at a point one mile north, northwest of Hoosick Falls, and the following species were recognized. *Solenopora compacta*, *Maclurea* sp.?, *Lituites* sp.?, and *Orthoceras* species undetermined."

In the first published section of the "Taconic System," the "Shales of the Champlain Group," are represented as resting unconformably against and on the Taconic slates. Dr. Emmons gives a section of Bald Mountain, in the town of Greenwich, Washington County, New York. This section was given with the intention of showing the unconformity between the Taconic slates and the Calciferous formation. The section of Bald Mountain as given by Dr. Emmons, proved upon examination that the strata contained a fault, and are there pushed over on the Chazy terrane, and that the "Upper Taconic" is not unconformably subjacent to the latter or to the Calciferous sandrock. About two miles north of Bald Mountain there occurs a mass of limestone adjacent to the fault line and contains *Orthis testudinaria*, *Strophomena alternata*, *Maclurea* and other gasteropodi, *Calymene senaria* and fragments of *Asaphus platycephalus* a fauna belonging to the Lower Silurian system.

"Another illustration of the supposed overlap of the Champlain upon the Taconic terrane is given in the American Geology, pt. 2, p. 72. It is in the Township of Greenbush, opposite Albany, New York, on Cantonment Hill. There a mass of Trenton limestone is caught on the line of the great fault separating the Champlain and Cambrian strata, as at Bald Mountain and other places in Washington county, and also in Vermont. The strata of the Hudson and Trenton terranes are broken and displaced, but there is no evidenee that the Trenton was deposited upon the upturned edges of the Cambrian or "Upper Taconic" slate; and, on the line of the same fault twenty miles to the south, in the township of Schodack, Mr. S. W. Ford discovered an unconformable contact between the dark-drab siliceous and micaceous shales of the Cambrian and the dark argillacroni shales of the Hudson Terrane.

Mr. Ford kindly took me to the locality which he has so well described, and I saw the the "hade" of the fault, the slickensides on the opposing surface, and broke out graptoliter from the Hudson shales beneath, and within six inches of the fault line.

A short distance south the limestones interbedded in the dark-drab shales gave us an abundance of characteristic Cambrian fossils."

"Dr. Emmons's errors are nearly all traceable to his trust in lithologic characters of the various formations within the Taconic area. He established the "Taconic System" in 1842 on the differences in the lithologic characters of the Taconic rocks and those of the New York "Lower Silurian."

"The unconformity between the "Taconic System" and "Champlain" series, announced in 1844-'47, was primarily based on the similarity of the lithological characters of the Calciferous sandrock of the Lower Silurian and the calciferous sandrock of what we now know to be, from its contained fossils, a part of his "Upper Taconic" series. Again when the latter (calciferous sandrock of the Cambrian) was pushed over on to the dark shales or the "Lower Silurian" on the line of the great fault, he identified the latter shales with the "Upper Taconic" shales and thus obtained an unconformity, as at Bald Mountain, between the Lower Silurian and Taconic strata. He failed to recognize the fact, shown along an outcrop of a hundred miles or more, that the Potsdam and, frequently, Calciferous terranes were represented in the geological sections by a shale undistinguishable from the shale of the Hudson terranes; also that the same conditions occur in the Champlain valley, in the towns of Fort Ann, Kingsbury and Hartford, Washington County, New York, and that in several localities the Trenton limestone is replaced by shale. This explains much of the confusion in his stratigraphy and also, in that of Professor Jules Marcou, in northern Vermont, who was misled in the same manner. The shales containing the Primordial fauna are usually lithologically dissimilar from the dark argillaceous shales of the Lower Silurian, but, as Dr. Emmons included the dark graptolitic-bearing shales of the Hudson terranes within the Taconic area, in the "Upper Taconic," he necessarily compared and identified the black shales of the Lower Silurian with the "Black Slate" of the "Upper Taconic."

In 1847, Dr. Emmons did not consider the two species of trilobites as characteristic of the true Taconic slate, but of the overlying "Black Slate," which he considered to be pre-Potsdam, from the evidence of the Bald Mountain section.

The comparison made by Dr. Emmons between the fossils of the "Black Slate," and the Primordial fauna of Barrande, in 1859 came too late to anticipate the identification of the Primordial fauna in the Cambrian of Sedgwick, for the Cambrian System, as used by me, was correctly identified, paleontologically, by M. Barrande, in 1854.

January 20th, 1851, M. J. Barrande read a paper before the Geological Society of France, upon the "Silurian Terrane of England." He presented a sketch of a section fron Wales showing the Archean and resting upon it, the stages C and D, of the Bohemian section or the strata of the First or Primordial fauna and the Second or Lower Silurian fauna. Above the Lower Silurian the Upper Silurian is shown as resting unconformably upon the latter. In this paper the Lower Cambrian of Sedgwick is identified by organic remains, through comparison with the established succession of fossils in the Bohemian Basin."

"M. Barrande visited England in 1851 and determined the age of the Primordial fauna found in the typical Cambrian area of Wales before he knew of the existence of the vestige of the Primordial fauna published by Dr. Emmons. Subsequently, upon the evidence of Dr. Emmon's published stratigraphic sections, showing that he, Dr. Emmons, knew the fossils to be stratigraphically pre-Potsdam, M. Barrande was misled into crediting him with the discovery (in 1859) that was based on errors of field observation.

I endeavored to make, in 1886, an argument for the use of the name Taconic for the middle division of the Cambrian System, but it failed in the light of latter results of field work; and now I think that geologic nomenclature will be benefited by dropping the name entirely. Based on error and misconception originally and used in an erroneous manner since, it serves only to confuse the mind of the student, when applied to any formation or terrane. There are several reasons for the foregoing conclusions that perhaps it is best to here state.

1st.—The name is not applicable; the Taconic range, from which the "Taconic System" was named, is not known to contain a fossil of the first fauna or a formation that contains one elsewhere. The "Upper Taconic" slates lie west of the range and the "Granular Quartz" series east of it, and the range is formed of strata of the Trenton-Hudson Terrane.

2d.—The "Taconic System" was considered pre-Potsdam, on two suppositions (a) the Calciferous sandrock of the Lower Silurian is unconformably superjacent to the Taconic slates on the west; (b) that the variation of the lithologic characters of the Lower Taconic rocks, from the New York Lower Silurian, indicates a distinct system of rocks." "We find that the unconformity (a) was based on errors of field observation; and (b) that the "Lower Taconic" rocks are of Lower Silurian age, with the exception of the lower quartzite, which is Cambrian and conformably subjacent to the Lower Silurian.

3d.—The claim of priority of discovery of the Primordial fauna is invalidated by the fact that the fossils found in the Taconic slate were referred to a pre-Potsdam horizon on an erroneous interpretation of the stratigraphy and not from comparison with a known fauna that had been stratigraphically located in any clearly defined geologic section.

4th.—It is only a fortunate happening, and not a scientific induction based on accurate stratigraphic or paleontologic work, that any portion of the "Taconic System" is found to be where Dr. Emmons placed it.

5th.—The application of the principles stated at the beginning of this paper rules out the name Taconic from geologic nomenclature.

(It is a rule of geological nomenclature that the whole series of rocks be developed in the town, mountain, or along the river from which the name is derived.)

6th.—The term Cambrian antedates Taconic for a stratigraphic system and also, as a correctly-defined faunal definition.

The Cambrian System as it now stands today, is divided into three ages, based upon paleontologic and stratigraphic evidence. The Lower Cambrian, the type of which is represented by the (Georgia) terrane of Georgia, Vermont.

The Middle Cambrian by the types (Braintree) of Massachusetts, (St. John) of New Brunswick, and (Avalon) of Newfoundland under the name Acadian.

While the Upper Cambrian is represented by the (Potsdam) errane of Eastern New York."

FORMATIONS OF THE CAMBRIAN SYSTEM.

CAMBRIAN.	Upper Cambrian.	Potsdam.	TYPE. Sandstones of the north and east sides of the Adirondack Mountains of New York and adjoining parts of Canada.
	Middle Cambrian.	Acadian.	TYPE. Shales and slates of eastern Massachusetts (Braintree) New Brunswick (St. John), and eastern Newfoundland (Avalon).
	Lower Cambrian.	Georgian.	TYPE. Shales and limestones of western Vermont, Georgia and Red Sandrock.

PART II.

The Geology of St. Albans and Vicinity.

Upon examination of the rock formation in St. Albans, the result showed that a large portion of the town was of Cambrian formation and as the type locality of the Lower Cambrian was located in the border town Georgia it was thought best to commence and run the formation from an east and west line, starting from the Noah Parker farm in the town of Georgia through St. Albans and as far north as the Missisquoi River in Swanton, the bordering town on the north.

Particular pains have been taken with five of the formations in St. Albans, two for their great commercial value and three for their value in geological study.

1st. The Swanton Marble.
2nd. The Chazy Limestone.
3rd. The Trenton Limestone.
4th. The Intra-formational Conglomerate.
5th. The Noah Parker Horizon.

WINOOSKI, OR SWANTON, MARBLE.

Under the title Winooski Marble, in Volume 2 of the Geological Survey of Vermont, pages 774-5, the following is taken:

"The first quarries opened were in Colchester, near Mallett's Bay, by Hon. David Reed of Winooski Falls, he selected the name for the new marble and called it after the beautiful river that flows along near his dwelling. This marble is valuable in color and composition, some varieties are found in laminated beds, that are easily separated, while others are destitute of any evidence of stratification, but occur in solid masses and split with difficulty in any direction.

The prevailing color is red. It occurs in mottled blotches of every conceivable shape and shade in the same specimen. In some cases a shaded green forms the ground color, through which runs various shaded tints of a bright pink or reddish-brown. These varieties are consequental upon the composition of the rock, which is evidently different in localities remote from each other, and in some cases there is a perceptible difference in

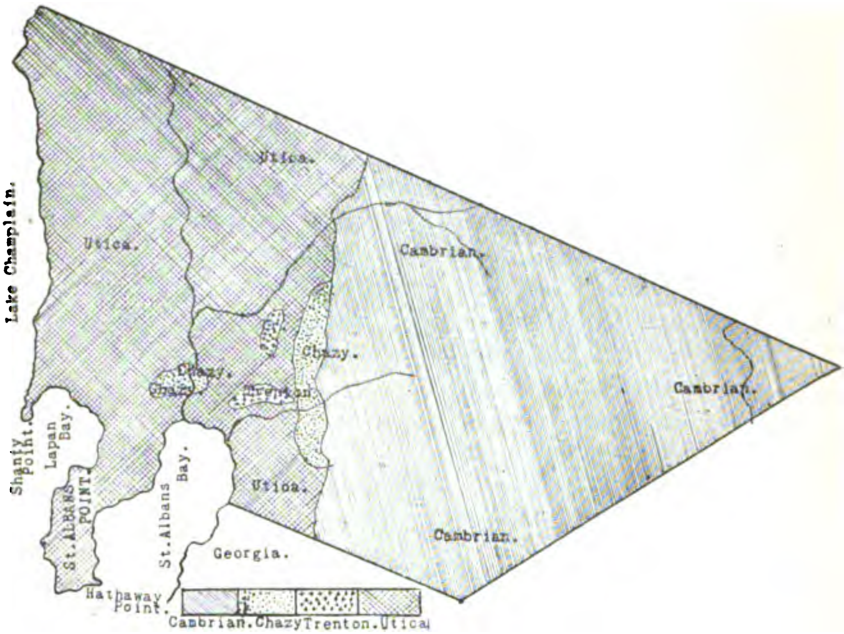

FIG. 3. Map of Geological Formations, in St. Albans.

contiguous beds. The variety of Winooski marble called "Mosaic Marble" from its resemblance to artificial mosaic work. This usually has a reddish color and upon examination is found to be principally composed of fragments of rocks, varying in size from a barley corn to blocks a foot or more in diameter, which appear to be promiscuously piled together after which they were cemented together with a substance having much more lime in its composition than the fragments themselves. This cement has a lighter color than the other portions of the mass, which gives it its beautiful sparry and variegated appearance."

The composition, as determined by an analysis by C. H. Hitchcock, Chemist of the Geological Survey is

Carbonate of lime	35.31
Carbonate of magnesia	42.23
Silica	10.30
Alumina and iron	12.25
	100.09

It is not an uncommon occurrence where the contiguous beds of the marble are in plain view, to find that the mottled variety is often divided by that of the pure red variety and that the demarkation is sharp and clear, there seemingly being no gradual passing of the one to the other. On the land of Henry Brigham in the town of St. Albans, at which place the formation lies somewhat like a huge flight of stone steps, this characteristic of the marble can be plainly seen.

The thickness of the beds varies greatly, often changing from a foot to that of many feet at localities not remote from each other. The lower beds of the marble in this locality can hardly be recognized, so faint are the slight streaks of red that are found upon its freshly broken surface.

Beneath the marble are found impure limestone and arenaceous shales.

To see and understand the condition of the Cambrian formation in this portion of northern Vermont, one should cross and recross the formation from east to west, starting at the type locality at the Noah Parker farm in Georgia, Vt., and he can safely end the investigation at the Missisquoi River in the town of Swanton. Having done this he will be forcibly reminded that, either the overthrow of the Cambrian formation left on its way many of the rocks that are found in the Georgia terrane or that they were not deposited further north, and that many unconformities of stratification exist that are not noticeable, on account of lack of opportunity to see an actual contact of each separate formation one with another.

The seemingly fragmentary condition of the so called "Mosaic Marble" exists in every specimen of the clouded marble that is found in that particular formation, of which the Barney Marble Company of Swanton find three varieties at their quarry and this does not include the pure red variety that is found interstratified with the colored marble.

Careful research of the formations below the marble results in finding at least three distinct varieties of fossil fucoids. These can be easily traced up to the formation containing the "Mosaic Marble." The pure red variety that is found between the clouded marble contains many fossils among which the fucoidal markings are the most abundant, and three varieties have been found in this formation. The clouded marble on top of the red is covered by sandstone, which is capped by arenaceous shale which is actually made up of these fossil fucoidal remains.

One can trace the fucoidal remains through the formations below the Winooski Marble and finding them in abundance in the interstratified red variety and passing above into the sandstone, in which they were found only sparingly, and then only in the rock where it had become disintegrated and broken by the action of frost, which condition was not found abundantly, and then into the overlying shale, in which they again become so plentiful that the shale seemed entirely formed of these fucoids.

In many localities the marble is found in such condition that it is impossible to quarry it in large blocks, this is due partly to a light green substance that is found in the marble and causes the rock to split, but in no instance of splitting have I noticed a single sharp or angular break that would indicate a conglomerate or brecciated condition of the marble; but I have seen many indistinct markings that closely resembled the fucoids of the formations both above, between and below the marble.

Based upon these facts and from the many forms that are seen upon the polished surface of the marble that resemble fucoidal remains, I am of the opinion that the many beautiful patterns seen in the marble are due to the almost solid mass of these fucoids from which the rock is formed.

At a point about half way to the lake shore, the distance of three quarters of a mile from the Noah Parker horizon, is a cliff thirty or more feet in height, in which may be seen all the varieties of Winooski marble.

Passing northward the formation runs in an unbroken line until the land of Manchester Chase is reached on the highway leading from Chase's Corner to St. Albans Bay.

A short distance north the formation is seen on both sides of the road and continues in that condition until a short distance beyond the residence of Bert Rankin where it crosses to the east side of the highway and continues until just before reaching Mill River it crosses the highway to disappear beneath the opposite side of the river bank.

Going northward from Mill River no outcrop occurs until the land of Dr. T. R. Waugh, situated on the eastern side of the highway leading from Mill River to St. Albans Bay, is reached. Here a low outcrop shows itself above the surface, which gradually rises as it passes northward onto the land of A. C. Bingham, where the Cambrian formation, capped by the marble, rises above the low outcrop of chazy limestone in a high cliff, overlooking the waters of St. Albans Bay. Then it passes in an unbroken line onto the land of J. B. Foss, at which locality a large amount of the marble can be seen. This is one of the largest exposures on the trend; it passes unbroken over the old Whitney Jewell farm and on land owned by Hugh Hamilton on the south side of the main highway leading from the City of St. Albans to St. Albans Bay, here the line becomes broken, but makes its appearance on the north side of the road on the lands of John Button and Phillip Pelkey. Here a large outcrop occurs and considerable quarrying has been done, chiefly for building stone.

It passes in an unbroken line across these farms and onto the land of Henry Brigham where the formation has a large east and west exposure.

On the land of Caleb Jewell west of the Brigham land, a vein of hematite iron ore was found in the marble, the iron was of a good quality and the vein was prospected to the depth of eighteen or twenty feet, the iron continued good to the last blast, which shook the last of the ore from the smooth face of the marble beyond, the pocket was empty, beyond on all sides only marble remained.

From here it passes in a northerly direction still unbroken, through the adjacent farms to the land of Thomas Cahill at which point it crosses the highway, north of the John Bird place. The rock now appears on both the east and west sides of the road for a few rods, and then passes beneath the surface, this is the last exposure in the town of St. Albans.

From here to Swanton Junction a distance of over one mile the marble remains concealed beneath the surface, with the exception, that a few rods south of the lime kiln where the Central Vermont Railway has been cut through a ledge of gray sandstone, at the base of which can be seen a small exposure of the marble. At the Junction the ledge lies close to the main highway leading from St. Albans to Swanton, on the east side of the road on the land of C. E. M. Bullard. It may be well to note here that many years ago excavations were made in the seams of the marble in hope that the usual dream, that is accountable for many similar exploits, would prove true, and that the treasure of lead and silver ore would be found as seen in the dream. Although no lead or silver rewarded the labor it brought to the surface a species of asbestos, known as mountain cork, hematite iron ore and a fine grained clay, of a light yellow color. The clay proved to be of some value, and a limited quantity was dug and sold, but for some reason, although a demand still exists for it, the work has been abandoned and the shaft left open and is slowly filling up.

The exposure on the Bullard farm is but a few rods long, but rises to a height so that large blocks have been taken from the ledge from above the surface of the ground and the remaining ledge seems firm and sound, an exception to many of the outcrops, for as a rule the marble is badly seamed and large quarried blocks are not attainable at all localities where the marble is found.

On the west side of the highway and a short distance north of the point of the actual junction of the railroads a small isolated outcrop is seen, from which some marble has been taken; for a short distance northward no marble is seen until the land of Louis Laflam, situated on the west side of the highway, is reached, here an outcrop occurs which runs northward on the land of Amos Skeels, from this point following the trend northward for the distance of one mile no marble is seen until the south line of land lying on the east side of the highway, belonging to Mrs. Jane Wood is reached, here the Cambrian sandstones stand above the road in a perpendicular cliff some sixty feet high at the base of which the marble can be seen passing beneath the overlying formation. The next outcrop is a surface one on the land of Miss Mary Dorman over whose land it passes to the land of Chas. Bullard.

It is here the Barney Marble Co. quarries are located, over which land the marble passes in an unbroken line and disappears beneath the surface of the earth a short distance before reaching Missisquoi River.

CHAZY LIMESTONE.

The Chazy formation in this section of Vermont is represented by a fine grained, light blue, or as it is sometimes called dove-colored limestone.

The formation is well known for its production of a superior white lime. That it has been used for this purpose for a long time is evidenced by the number of old and now unused kilns that can be seen along its trend in this section.

Analysis shows the limestone is as follows:

Lime	55.83
Magnesia	Trace
Iron and Alumina	.10
Silica	.40
Carbon Dioxide	43.65
	99.98

The only evidence, other than its stratigraphic position, that the formation is Chazy, is an occasional weathered *Maclurea magna* that can be seen on its surface, where the waters of Mill

River have worn the rock smooth, and the wear of time has brought the fossils, which are formed of harder material than the rock in which they were enclosed, into relief upon its surface.

The broken rock shows only a smooth surface, destitute of any markings of organic remains.

The first appearance of this formation in this section is seen northwest of the residence of E. R. Wilcox in the town of Georgia; here the formation rises out of the lake and shows itself for the first time after passing beneath the water near the north end of South Island.

For a short distance it forms the bank of the lake, rising a few feet above high water mark and shows evidence of the wearing power of the waves, by the many miniature caves they have formed in the rocks.

North of the house it crosses the highway where a large exposure can be seen. Passing northward there are several small exposures on the lands of Mr. J. Patterson and Miss L. Evarts.

At the "Pines," one of the noted camping grounds on the banks of the "Great Back Bay," the now small stream known as Mill River, has cut its way through the limestone for a long distance forming a deep channel now only partially filled by water.

Far above the water of today, the rocks exhibit many evidences of the time when the stream filled the channel, for the sides of the rock are filled with circular holes, formed in the rock by the grinding action of stones, whirled round by the water.

On the eastern bank of the river the limestone passes beneath some fifty feet of Champlain drift and remains concealed until the farm of Dr. T. R. Waugh is reached, where a small outcrop appears on the east side of the highway. Here and on the adjacent land to the north owned by A. C. Bingham, several small outcrops occur which barely appear above the surface. North of the Bingham residence an outcrop comes to the surface which continues on the land of Mrs. Mary Potter whose land adjoins the old Haynes property where a large exposure of the stone occurs on the hillside pasture. Northwest of this locality the Trenton Limestone can be seen for the first time. From this pasture the formation crosses the lands of Albert Greene and Frank Bushee.

Northwest of the dwelling of J. B. Foss an outcrop of this limestone appears, that forms a small hill, isolated, and to the west of the Chazy outcrop as the general trend is found in this section.

From this point of the pasture land of Frank Young, situated on the east side of the highway leading north from the main road passing between the city of St. Albans and St. Albans Bay, and directly opposite the home of Stephen Albee a distance of one-half mile, the intervening space is covered by Champlain drift. A small brook makes its way down the valley about midway between these two points, from the banks of which have been taken large quantities of sand, gravel and clay for commercial purposes.

The bivalve shells *Sanguinolaria fusca* and *Saxicava rugosa* are found in these sands in abundance. Many of the shells are found with their valves intact, a fact that would lead one to believe that they once lived in the ocean that formed these beaches and their presence in the sand is not the result of transplantation by water from other localities.

On the land of Mr. Young the limestone rises above the surface in an abrupt ridge sloping to the north. It crosses the highway and is seen on both the east and west sides of the road until a point is reached just south of the home of John Button situated on the eastern side of the highway. Here the stone passes beneath the surface. From here to the land of Chas. Brooks the Cambrian formation lies close beside the road on the east, to the west as far as the eye can see, not a rock makes its appearance above the surface. In fact throughout most of the road, after a distance of fifty feet is passed, no rock appears above the surface, with the exception of here and there an outcrop of shale, until the shore of Lake Champlain is reached.

Near the north line of the Brooks farm on the east side of the road the limestone is seen on the side of the hill, at which point the Cambrian lies above it forming a steep cliff.

So far along the line of the Great Fault the actual contact of the Chazy limestone and the sandstone of the Cambrian formation has not been seen. At this locality the Chazy formation is not only seen passing under the Cambrian, but here is a large mass of Cambrian rock forming a ridge for a short distance and some fifteen feet in height, which not only rests upon the limestone but is so placed that the Chazy formation appears on both the western and eastern sides of the ridge, from which it can be seen passing under the main body of the Cambrian.

The exposure continues northward across the adjoining land of Marcellus Pierce, where the outcrop is over one hundred feet in width and the Cambrian sandstone rises above it forming a bluff sixty feet in height.

Actual contact between the two formations can be seen at this locality. Near the north line of the Pierce farm the Chazy passes beneath the Cambrian formation.

Its next and last outcrop in the town of St. Albans is near the north line of land owned by A. B. Collins at which place it passes over the land of John P. Rich situated in the town of Swanton. At this point the lime kilns of John P. Rich were once situated, but they have been abandoned for newer fields. A short distance north of this locality the limestone forms a high ridge, the outcrop here is very large, it is here the lime kilns of W. B. Fonda are located. North of these works the line again becomes broken and its next appearance is on the land of Amos Skeels, where it again passes beneath the surface, to be next seen about forty rods north on the land of Andrew Bebee, through whose farm passes the Missisquoi River.

TRENTON LIMESTONE.

In the eastern portion of the village of St. Albans Bay, on the land on which stands the Church "Our Lady of the Lake," occurs the first outcrop of Trenton in St. Albans. The outcrop is small and shows itself but for a short distance. Here the four formations that comprise the entire geological series of this section, Trenton, Chazy, Utica and Cambrian, can all be seen in a small space.

This is the only locality in the town of St. Albans where the four formations meet.

Here the Trenton crosses the highway and several outcrops occur on the east side of the main highway near the Foss farm at which locality it passes beneath the surface and next appears to the north on the land of Stephen Abler on the west side of the highway. This is its last appearance in the town of St. Albans.

Except near the church the formation rises but little above the surrounding country and is smooth and rounded by glacial action.

The rock is hard and but few good fossils are obtainable from the outcrops, but from the waste scattered around many beautiful specimens have been secured.

LIST OF TRENTON FOSSILS FOUND IN ST. ALBANS.

Prasopora lycoperdon, *Say.*; *Lingula curta*, *Con.*; *Lingula elongata H. Orthis subquadrata*, *H.*; *Orthis testudinaria*, *Dal.*; *Schizambon dodgi*, *Wal.*; *Schizocrania filosa*, *H.*: *Peristrophia hemiplicata.*; *Whitella ventricosa.*; *Strophomena alternata*, *Con.*; *Trematis terminalis*, *Emm.*; *Ambonychia undata*, *Emm.*; *Holopea symmetrica*, *H.*; *Bucania punctifrons*, *Emm.*; *Rhaphistoma lenticulare*, *Emm.*; *Bellerophon bilobatus*, *Sow.*; *Holopea symmetraca*, *H.*; *Conularia trentonensis*, *H.*; *Cyrtolites compressus*, *Con.*; *Cyrtoceras subangulatum*, *D'Orb.*; *Orthoceras junceum*, *H.*; *Orthoceras olorus*, *H.*; *Asaphus gigas*, *DeKay.*; *Ceraurus pleurexanthemus*, *Gr.*; *Trinucleus concentricus*, *Eat.*

INTRA-FORMATIONAL CONGLOMERATE.

DEFINITION OF TERM AND ILLUSTRATION.

"An intra-formational conglomerate is one formed within a geological formation of material derived from and deposited within that formation."

An ocean for ages had been covering with its sediments, the remains of the inhabitants that lived within its waters.

Nature in her great laboratory had changed the sediments, with the enclosed organic remains, into stone of various kinds, while the waters of the ocean still contained a living fauna, descendants of those enclosed within the rocks below the ocean bottom. These rocks were by some convulsion of nature thrown upwards and above the surface of the water, some portions falling immediately beneath the water and escaping the eroding action of the waves, thus retaining their angular shape, while the rocks that remained above the water were buffeted by the waves, lost their angular proportions and became rounded and smooth.

A subsidence of the ocean bottom caused the rocks to sink below the surface of the water, in which they were born, and the ever falling sediments cemented them firmly together, into a new, old rock, which new formation exhibits the peculiar characteristics of the different rocks of which it is formed.

This conglomerate is formed of dark colored fine grained limestone, bluish or dove-colored limestone, arenaceous shale in which, in some instances, are found nodules of pure limestone and enclosed water worn pieces of bluish colored slate, which in many specimens are oval, sandstone resembling quartzite, arenaceous limestone in which the enclosed grains of sand are dark, thus giving the rock a mottled appearance, and a light colored sandstone.

The rocks forming this conglomerate vary in size, from small fragments, to bowlders weighing many tons.

Some of the pieces show but little, if any, abrasion and the broken surface is sharp and rough as those of a recently broken rock, but the larger proportion of them are smooth and water worn.

The first appearance of this formation in the State, is near the north line of Georgia, on the north side of the road leading from Mill River to the home of Wm. Caldwell, on the highway leading from Georgia to St. Albans.

At this point but little of the formation appears above the surface, the general appearance here is that of a massive dark-colored arenaceous limestone, as the brecciated nature of the formation does not appear at this locality at its best.

Passing north east without a break, to the north line of Georgia, the formation disappears beneath the surface, to again appear on the farm of Wm. Walker in the town of St. Albans. At this locality, for the first time the shale, that farther north on this range, is seen interstratified with the limestone, makes its appearance, on the west side of the terrane at the base of the cliff.

At no place in St. Albans is the brecciated condition of this formation better represented than at this locality, although some of the limestones are missing here that are to be seen a short distance north east, the fact that the surface of the rocks which has been recently exposed has been smoothly planed by glacial action, tends to bring out the structure of the formation in bold relief.

From this point to the pasture of Henry K. Adams on the north side of Lake street, a distance of one and one half miles, the formation is covered by the Champlain clays and sands.

At this locality the rock is exposed for a distance of two hundred feet, north and west, and the shale that is found associated with the formation has a large exposure to the east and west.

From this pasture land for a distance of some two miles the rock remains below the surface, until a short distance south of the Montefore place on the main highway leading from St. Albans to the town of Swanton, it makes its appearance and crosses the highway, only to disappear a few rods further north.

On the main highway leading from St. Albans directly to Highgate Falls the formation again appears for the last time in St. Albans, and then passes into Swanton.

Here the formation is represented by the shale, seen to the west of the limestone at the Adams locality. Further north the limestone appears, passing from Swanton into Highgate, to the bank of the Missisquoi River.

NOAH PAKER HORIZON.

The type of the Lower Cambrian terrane is represented by the shales and sandstones. The formation by a series of ledges passes westward from and over the western part of the Noah Parker farm, situated in the town of Georgia, Vermont.

The distance across from the starting point to Lake Champlain is about one and a half miles.

Directly back of the late Noah Parker residence is a circular hill at the base of which a fine arenaceous shale makes its appearance.

As the formation passes northward the shale becomes coarser and the bedding uneven, until at the top the shale is replaced by sandstone.

About half way up the hill and on its eastern portion a shale appears that is easily split, exhibiting a smooth surface, but it either splits through its stratification or is destitute of fossils.

The entire length of the hill, from its appearance until it passes beneath the surface is but a few rods in length.

In following this formation northward these shales and sandstones will be spoken of as the Noah Parker Horizon.

This is the last exposure of this horizon in the northern portion of Georgia, although the formation to the west continues northward the Noah Parker Horizon passes beneath the surface at this place.

As the formation passes northward the distance across the terranes shortens, until the shales and sandstones west of the Swanton marble, which is midway in the Georgia terranes, disappear and the marble becomes the western boundary of the Cambrian.

The next appearance of this horizon is on the land of E. H. Brooks in St. Albans and directly back of the William Hickok residence, here the horizon is represented by the central and eastern portion of the Noah Parker group of rocks.

Here a break occurs and the next outcrop is on the land of H. P. Duclose, where the sandstone of the upper part appears ; it crosses the late Whitney Jewell farm and disappears just before reaching the north line of the farm, to appear on the line in a high cliff. Here the middle, eastern and upper portions of the horizon appear. At this point the formation crosses the main highway leading from St. Albans to St. Albans Bay.

West of the John Fallen place and across the highway north, the formation becomes a light blue, changing to nearly a white sandstone with small outcrops of shale. This upper portion of the horizon continues until just south of the residence of S. J. Brigham where it passes beneath the surface and is next seen on the west side of the Central Vermont Railway track; here the stone is nearly white.

On the eastern side of the railway a small outcrop of shale appears that barely reaches above the surface.

The formation continues northward along the western side of the railway, and with but a single break, to where the middle and upper parts of the Noah Parker horizon appear.

This is the last appearance of the horizon in the town of St. Albans.

The next appearance is in the town of Swanton jnst north of the John P. Rich residence, on the highway leading from St. Albans to Swanton, at which place the electric railway cuts through the formation, passing northward over the Bullard land, and to the land of J. P. Kelley (the old Cushman farm) where the central and upper portion of the horizon appear.

At this locality a break occurs, and it is seen next on the land of C. E. M. Bullard over whose land it passes to near the banks of the Missisquoi River.

On the line of the "Great Fault," west of the Noah Parker farm in the town of Georgia, where, from the last exposure of the Cambrian rocks, the land slopes gently to the west to meet the waters of Lake Champlain, the intervening area is being covered by Champlain drift, this rock continues down to the shore of the lake, at which place the waters have laid bare the Utica Shales the formation upon which at this point the Cambrian formation rests. This is not as a conformity or unconformity of stratification, but as a result of an overthrow of the Cambrian formation. The Cambrian rocks have by some great upheaval of nature been shoved from the east upon and over a newer formation, the Utica Shale, the last formation to be laid down in this vicinity.

But a small exposure of this shale is to be seen in this vicinity and a few rods further north on the shore line the formation passes beneath the surface the stratum dipping to the east.

No actual contact of these formations can here be seen.

Passing northward the shore is covered by cobbles and pebbles and but few large bowlders can be seen. The bank rises but a few feet above low water mark.

On the land of James Patterson the Chazy limestone forms a low headland, which dips gently to the north and passes beneath the surface. This is the only exposure of the Chazy on the lake shore in this vicinity, the strike carrying the formation inland from this locality.

Beyond this headland the shore becomes sandy and low, the high water and waves carry the sand inland thus forming a ridge back of which a small marsh lies which extends northward and runs into Mill River. This portion of the Great Back Bay is known as the "Pines" and "Pattersons" and is a favorite camping ground, many cottages having been built beneath the pine trees from which the locality derives its name.

It may be well to mention at this time that these ever shifting sands contain many stone relics of Indian manufacture. Hundreds of arrow and spear points have been found in these sands, but the supply still remains unexhausted.

It is at this locality that the small stream known as Mill River makes its way into the lake. North of the river the land rises gradually until it reaches a point about eighteen feet above the water and the shore close to the bank is strewn with bowlders of gneiss and sandstone, some of many tons in weight, which have been pushed by the ice firmly against the bank. From the large bowlders to the water the shore is strewn with small cobbles of many formations, some having come long distances, for in a piece of sandstone picked up upon the shore I found the markings of the fossil Lepidodendron a coal plant of the Carboniferous system. It is here that the shore passes into the town of St. Albans. Passing by the village of St. Albans Bay where the shore line has been changed by the hands of civilization to south of the creek bridge, at which place a marsh empties into the lake, we come to the eastern shore line of St. Albans Point. South from the creek the bank of the lake shore becomes elevated and forms a low bluff, with an occasional outcrop of Utica Shale until School

House Point is reached, where a small bay occurs, heretofore the beach has been strewn with the usual bowlders and pebbles and rock waste, but now it is low and sandy hardly above the level of the water. Here a marsh makes its way across the point and connects with the lake just south of Jimmies' Rock on the western shore of the Point in Lapan Bay. From the low sand shore the bank gradually rises until a high bluff is found of Utica Shale on the land of Hiram Hathaway, which continues for a half mile and then slowly drops to a low beach just before reaching a point where the beach turns towards the east, here a small bay occurs, formed by a high point of shale which extends for a considerable distance into the lake. On the south and eastern portion of the point the water continually washes against the face of the cliff and the bottom is strewn with rock waste torn from the face of the shale. On the north eastern side of the point, in low water a flat plane of the shale extends outward from the base of the point, which dips to the east and passes into the water of the lake.

From this point the shale may be seen in an almost unbroken trend, passing the extreme end of the point to where the shore line has turned northward, here the shale passes from sight and white sand replaces the shale. Here the sand forms a barrier back of which a marsh forms in high water extending northward to Smith Brooks Point. From the sand beach the shore again becomes Utica Shale and continues almost unbroken until the low land where the marsh empties into the lake north of Smith Brooks Point is reached where the shore is a mixture of clay and sand.

The next shale is on the point of rocks known as Jimmies' Rock, here a small exposure is seen, which has the usual eastern dip.

From this rock northward and along the entire shore of Lapan Bay the shore is low and at first consists of a mixture of clay and sand until the bottom of the bay is reached; where the shore is entirely made of a fine, white sand, back of which a marsh forms in the high water of spring. The shore now turns southerly and becomes covered with bowlders.

Down the entire shore of Shanty Point the shore is low, and bowlder strewn, broken here and there by a strip of sand and clay until well down on the western side of the point the shore rises gently and the shale makes its appearance for the first time since leaving Jimmies Rock.

It is at this point on the shore of the "Great Back Bay" that the well known "Lake View House" is situated. North of these premises the shore is low and bowlder strewn, it gradually rises to the north and the Utica shale again appearing in the shore line it passes out of St. Albans into the town of Swanton.

West of the Chazy limestone, and covering the entire territory to the lake shore, including St. Albans Point wherever an exposure of rock appears, which in some instances forms long ridges running north and south, the rock dips to the east and is undoubtedly Utica Shale.

East of Main street in St. Albans the Cambrian formation consists of shales and sandstone.

Two lines of hills run into the town from Georgia and Fairfax.

Prospect Hill crosses the line between Georgia and St. Albans and runs a short distance into the town, where the chain becomes broken, a small outcrop belonging to this hill is seen in the city at the home of Charles H. Clark on South Main street.

East of England street the Stevens brook has cut its way through the same formation.

With the exception of a small outcrop of shale that barely comes to the surface, as it crosses Ferris Street, they are the only outcrops of the Cambrian within the city limits.

Back of the residence of Ex-Gov. E. C. Smith, rises Aldis Hill the continuation of the Prospect range.

The hill runs northward about a mile and then passes beneath the surface.

East of Prospect Hill a high range of rock formation passes into St. Albans from Fairfax and is at first known as Belleview and further north as St. Albans Hill.

Passing eastward over this range and near the line between St. Albans and Fairfield, the rock changes and the Talcose schist formation shows for the first time and passes eastward into Fairfield.

For the benefit of all who are now interested in Geology and also for those who in time to come may desire to obtain knowledge of the past ages, the written secrets of which are fast sealed in the rocks of this section, I will try to impart such knowledge as I have been able to secure as to the locations of horizons, where it may be possible to obtain the different organic remains that have been found in St. Albans and adjacent towns.

The area under consideration as shown by the attached map, is largely of the Cambrian formation, in which, until recent years, the geologists of the world had been able to find but few fossils, and the fauna of that age was a problem still to be solved. Time, labor and constant effort by those interested in the work has brought to light considerable information regarding the species living during that time, but there yet remains much to be done before the rocks have yielded up their last secret and the fauna of the now oldest rock formation bearing organic remains will be considered completed. And then the work will still go on, down lower in the formations below the last known Cambrian rock. Even now there has been found in the Montana Belt terranes, in the Greyson shales near the mouth of Deep Creek Canyon, a short distance above Glenwood postoffice, undeniable traces of older life, the actual identity of which still remains a mystery, but enough has been found to stimulate further research.

Vermont, with all her rocky hills, will still by someones patient work yield many more specimens to be included in the Cambrian fauna. The geology of the State is still in its infancy and a large amount of work must still be done, and some undone, before the task will be completed.

The so-called Swanton marble and its associate red sandrock are particularly rich with fucoidal remains. The great beauty of this marble depends most wholly upon these fossil fucoids, for the many beautiful designs exhibited upon its polished surface. *Salterella pulchella*, a small shell, is also seen upon the polished surface, but not plentifully.

The polished surface of the red sandstone exhibits no fossils and it is only when the rock has become disintegrated that fossils can be found in any number, although the surface of freshly broken rock sometimes shows fragments of fucoidal remains and the following:

Salterella pulchella, *Ptychoparia adamsi*, *Planolites congregatus*, and fragments of shells closely resembling *Nidusa festinata*.

The genus *Agnostus*, although a true Cambrian trilobite and found in Vermont, has only been found in the eastern portion of the City of St. Albans, in dark colored arenaceous shale imbedded in Champlain drift, which had been exposed during a spring freshet.

I know of no instance where it has been discovered *in situ* in the State, except that mentioned below, though several have been found on the Stevens brook within the city limits.

It was while searching for these minute trilobites, that I first discovered the brachiopod *Lingulepis accuminata*, the dark colored, somewhat tough arenaceous shale in which it was enclosed, was firmly held in the Champlain clay and associated with numerous bowlders of Swanton marble.

The fossils were sent to Mr. Charles D. Walcott of Washington, D. C.; for identification, who suggested that I make search for the *agnostus in situ*. Although I never found the *agnostus* in any other locality, two years afterwards I discovered the brachiopod in the shale, in the intraformational conglomerate situated in the pasture of H. K. Adams, on the north side of Lake Street, near the west boundary line of the City of St. Albans.

In a monograph on "Fossil Medusæ," written by Charles D. Walcott, Director United States Geological Survey, published in 1898, the following reference is made to "*Dactyloidites asteroides* in Vermont."

"I recently received from Mr. G. E. Edson of St. Albans, Vermont, an impression of a star-like fossil, which he found at Parker's quarry, Georgia, Vermont, in the coarse Olenellus shales. He calls attention to its resemblance to *Dactyloidites asteroides* and I am inclined to think that this identification is correct. The impression is quite clearly defined on the somewhat rough arenaceous shale, and the interior canals are clearly shown in three of the lobes. The specimen is represented in text figure 15."

This fossil was found in the central part of the Noah Parker Horizon.

Since this publication of 1898 I had the good fortune, this year, to discover in the same horizon on the land of J. P. Kelley in Swanton, Vermont, three *Dactyloidites asteroides*, on the same piece of shale.

Here the blue colored sandstone that represents the top of the Noah Parker Horizon is particularly rich with the remains of the trilobite, *Olenoides marcoui*. The formation is split by the frost and few pieces are found without an imprint on their surface.

One piece eleven inches by fourteen had over forty imprints of the heads and pygidia on its surface.

Hand specimens often showed two and more pygidia, finely raised on the slightly disintegrated rock.

The middle shale furnished one specimen, showing the head and tail attached to the middle portion of the body.

Several almost entire *Ptychoparia adamsi* were also found at this locality.

It was after a search of ten years that I discovered in the shale bearing the *Olenellus* fauna, an *Agnostus in situ* in the central part of the Noah Parker Horizon, on the J. P. Kelley farm.

In the town of Swanton and directly east of where the Barney Marble quarry is located, the Noah Parker Horizon lies close to the so called Winooski marble. Here this series of rock formation extend eastward from the marble, the horizon covering some forty rods in width, and is the largest exposure in northern Vermont.

Besides the usual shale and sandstones found in this horizon, there appears a lenticular mass of limestone which is very rich in fossils.

The following list of fossils were found at this locality:

Kutorgina cingulata, *Nidusia festinata*, *Iphidea labradorica*, *Rustella edsoni*, *Swantonia antiquata*, *Ptychoparia adamsi*, *Olenellus thompsoni*, *Olenellus vermontana*.

The central portion of this horizon is especially rich in fucoidal markings.

The Intra-formational conglomerate in Adams' pasture in St. Albans is rich in trilobitic remains, but I have been unable to identify them, at least four species have been found. Also *Lingulepis accuminata*, *Conrad*, *Nidusia festinata*, *Bill.*, *Salterella pulchella*, *Bill.*

It would be a hard proposition to decide which one of the rocks forming the conglomerate was the most liable to contain fossils, the different limestones, sandstones and shale scontain the same organic remains, but neither color nor composition of the stone seem to be any criterion as to whether it contains fossils or not. Two light or dark colored limestones may be found side by side a mere crack filled with calcite separating them, one will not show the slightest evidence of organic remains, while the other will be nearly all composed of tribolite remains.

The matrix in which the rocks are imbedded shows the same fauna as the different rocks that make up the formation.

The accompanying list of Cambrian species is not designed to be complete, but only to include such as were found by the author while searching for data for this article.

Nidusia festinata, *Bill.*; *Iphidea labradorica*, *Bill.*; *Kutorgina cingulata*, *Bill.*; *Lingulepis acuminata*, *Con.*; *Protorthis wingi*, *Walc.*; *Planolites virgatus*, *Walc.*; *Planolites congregatus*, *Salterella pulchella*, *Bill.*; *Miriodiscus parkeri*, *Walc.*; *Olenellus parkeri*, *Walc.*; *Olenellus thompsoni*, *Hall.*; *Olenellus (Mesonacis) vermontana*, *Hall.*; *Bathynotus holopyga*, *Hall*,; *Olenellus*, *marcoui*, *Whitf.*; *Agnostus sp.*; *Ptychoparia adamsi*, *Bill.*; *Dactylodites asteroides*, *Walc.*; *Hypseloconus sp.* *Rustella edsoni*, *Walc.*

As was stated in the account of the geology of Grand Isle County Professor H. M. Seely was a frequent companion of the geologist during the progress of that work. While examining the rocks of the Chazy, fossils of many of the lower animals such as sponges, bryozoa, and corals were observed and collected. Professor Seely undertook the critical study of these forms and in the Third Report discussed "SOME SPONGES OF THE CHAZY" and described and figured several species of

Strephochetus. In the Fourth Report the same author gave the results of his study of the "STROMATOCERIA OF ISLE LA MOTTE" with descriptions and plates. In the following articles Professor Seely has added to his previous papers the following:

I. CRYPTOZOA OF THE EARLY CHAMPLAIN SEA. II. BEEKMANTOWN AND CHAZY FORMATIONS IN THE CHAMPLAIN VALLEY, CONTRIBUTIONS TO THEIR GEOLOGY AND PALEONTOLOGY. This second paper includes

1. The Wing Conglomerate. 2. The New Genus Wingia. 3. Limiting Layers af the Chazy Formations. 4. The Isle La Motte Sandstone. 5. Lingula limitaris. 6. Monticuliporia insularis. 7. Prasopora hero n. s.

The author of this Report feels sure that paleontologists will find much of interest in these papers. They are the result of long and careful study of the forms discussed and are worthy of close attention. All of the species figured by Professor Seely are represented by specimens in the State Cabinet.

Cryptozoa of the Early Champlain Sea.

H. M. SEELY.

CONTENTS.

INTRODUCTION.

The title of this paper recognizes the existence of the Genus Cryptozoon as established by Professor James Hall.

It is proposed to bring together some facts within the knowledge of the writer, to record some observations and to discuss the genus Cryptozoon, chiefly in relation to occurrence, structure, distribution, horizon and relationships.

The occurrence of small rounded masses of rock inclosed in larger masses is a matter of common observation. Some of these, clear of outline, differing in age and character from the including mass, break out freely and we recognize them as pebbles. Others occur sometimes with sharp boundary, but most often they shade into the inclosing rock of same age and apparently have been gathered from the inclosing mass. These are known as concretions. Yet some of these rounded forms that have passed as pebbles or concretions, particularly as concretions, are neither of these; they are the remains of once living beings, particularly of animals of low type of life. These have lived, flourished and died at the horizons that now contain them.

HISTORY.

The Beekmantown and Chazy formations are both rich in disk like or spherical masses of varying size, many of them of unquestioned organic origin, but too many of them of still uncertain relationship.

Professor James Hall, in the Thirty Sixth Annual Report of the New York Museum of Natural History, transmitted to the Legislature, January 12, 1883, figured and described one of these disk like forms under the title *Cryptozoon proliferum*, a new genus, and a new species.

A much earlier observation, one more than fifty years before, had been made by Dr. J. H. Steele. Steele's description with illustration of like generic form at the early time appeared in the *American Journal of Science* June 1825, Vol. IX, pp. 16-19. The following extract is made from Steele's article entitled, "Oolitic Formation of Saratoga County, N. Y."

"In and near the road, which leads from Greenfield to Ballston-Spa, by the way of Rowland's mills, on the farm of Deacon Wood, there is a bank composed of a series of horizontal strata where the peculiar characteristic features of this formation are well defined and may be readily examined.

One of the strata, which compose the series at this place, presents a very singular appearance, and one which, if it occurs elsewhere, has never been noticed, so far as I am able to learn, by any writer. The surface of this stratum is fairly exposed for a number of rods both to the north and south of the bank beneath which it evidently passes; it is about two feet in thickness and has embedded throughout its substance great quantities of calcareous concretions of a most singular structure; they are mostly hemispherical, but many of them are globular and vary in size from half an inch to that of two feet in diameter; they are obviously composed of a series of successive layers, nearly parallel and perfectly concentric; these layers have a compact texture, are of a dark blue or nearly black color, and are united

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PLATE XXXIV.

Steeles original Figure of Cryptozoon.

by intervening layers of a lighter colored calcareous substance, either stalactical or granular, they are very thin and I have counted more than a hundred in one series. By breaking the matrix in which they are embedded, they drop out entire, and may be readily reduced to any smaller size, by merely throwing them upon the rock—the concentric layers easily separate, leaving the form exactly the same.

These interesting concretions appear to be confined solely to one stratum ot the series, and this stratum evidently accompanies the *Oolite* in its whole extent, and is undoubtedly a variety of the same series, the best characterized *Oolite* lying beneath, while those of a less definite character are regularly piled above it.

I have endeavored to represent the appearance of this singular stratum in the small sketch which accompanies this communication; it comprises a section of the rock as it presents itself in the road, near the bank above mentioned, and is intended to display a view of its edge and surface together with the superincumbent strata."—*American Journal of Science*, June, 1825, Vol. IX. Pages 17 and 18.

A copy of the above sketch is given on Plate XXXIV.

Professor William W. Mather in his report on the Geology of the First Geological District of New York, 1843, discusses the "Calciferous Sandstone" and the "Oolitic Limestone"; and under the latter title, pages 415-416, he quotes liberally from Steele's communication to the *American Journal of Science* and among his plates reproduces Steele's original figure.

A foot note, page 416, is of particular interest and is here given:

"Some of the round masses described as concretions analogous to Oolite are organic, and will be described in the Paleontological Report. Similar concretions and ovidal masses in a similar geological portion, and assimilated rocks, have been observed in various parts of the Valley of the Mississippi, particularly in Missouri and Wisconsin."

The description here promised waited long.

How Professor Mather reached his conclusion that this form was organic he does not state. The conclusion of a man of such wide experience and careful observation, an expert in so many geological topics carries great weight. Yet a knowledge of the steps by which he reached his point would be to us a cause of much satisfaction.

A long time seemed to be needed to differentiate the rounded masses that bore more or less complete concentric rings.

A master would do great service to science who could distinguish as well as give a name and place to these uncertain forms.

Professor Hall had separated and named a banded form, the genus *Stromatocerium*. New York Pal. Vol. I, page 48. He found his generic form in the Black River and apparently limited the genus to this formation. It is now known however that the Chazy below it contains several well marked and characteristic species.

Professor Hall years later did further service to science in this special field, by calling direct attention to another form which was neither *Stromatopora* nor *Stromatocerium* and which was found in a formation lower than the Black River, and than even the Chazy, in that which has come to be known as the Beekmantown. This he named as before stated *Cryptozoon*.

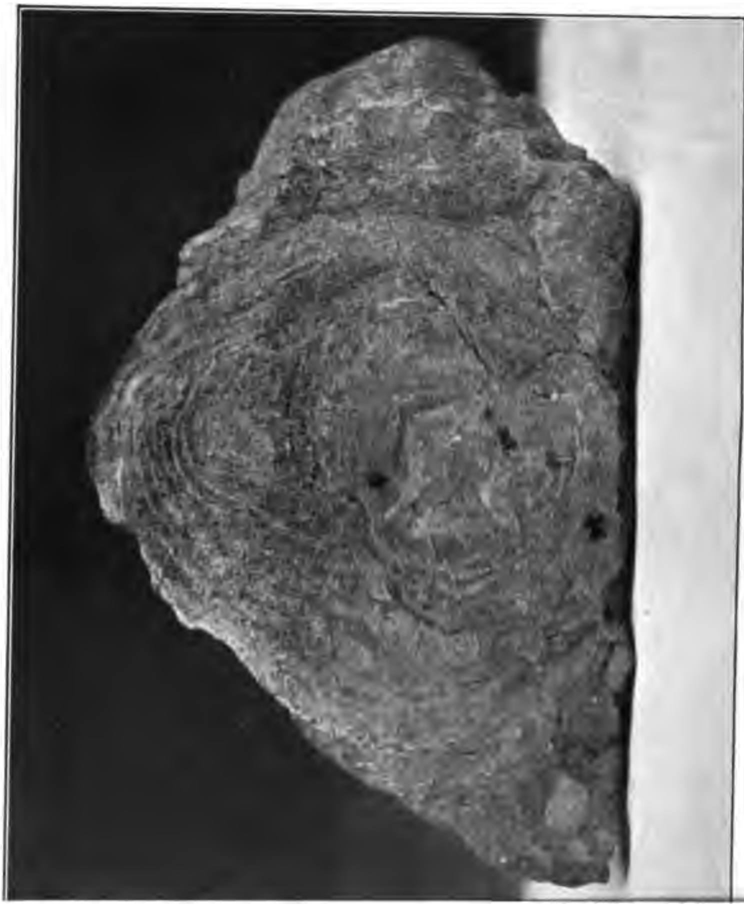
The genus once pointed out becomes in most cases easy of recognition. And the first carefully described form *Cryptozoon proliferum* seems to have segregating around it good modifications of the genus.

The essential portions of Hall's characterization of his new genus and new species are here given.

CRYPTOZOON. n. gen.

"Masses in beds of limestone in closely arranged circular or subcircular disks which are made up of concentric laminæ. It very often happens that within these larger disks there occur two or more smaller ones, each with its own concentric structure and exterior limitations and appearing as of leading from the parent mass. The form is hemispherical or turbinate, with broadest face exposed upon surface of the limestone layer, their growth has begun from a point below and rapidly expanding upwards has often extended one or two feet in diameter."

PLATE XXXV.



Cryptozoon steeli, n. s. Fresh fracture through the laminae. Natural size.

ERRATUM.

The cuts on Plates XXXV and XLIII were exchanged in printing. That on Plate XXXV is Monticulipora insularis and that on Plate XLIII is Cryptozoon steeli.

C. PROLIFERUM. n. sp.

"These bodies are made up of irregular concentric laminæ of greater or less density and of very unequal thickness. The substance between the concentric lines, in well preserved specimens, is traversed by numerous minute irregular canaliculi which branch and anastomose without regularity. The central portions of the masses are usually filled with crystalline, granular, and oolitic material, and many specimens show the intrusion of these extraneous and inorganic substances between the concentric laminæ."

Now with the genus clearly defined there follows naturally the study of other species if there be other species than the one described by the founder of the genus.

OTHER SPECIES.

Referring to the form earlier described by Dr. Steele, it will seem that it falls under Hall's genus *Cryptozoon*. Evidently however, it does not conform to the species *C. Prolifereum.* A decided gap, specifically wide, occurs. Particularly the shape and mode of growth which will be more fully considered later distinguish it. A specific name is needed to designate this early found form. It may be most properly known as

CRYPTOZOON STEELI. n. sp.

Plates XXXIV, XXXV, XXXVI, Figure I.

Referring back to the earliest description by Steele we may draw from it a fairly good characterization of the species.

A calcareous mass mostly hemispherical but not unfrequently globular; in size from an inch to two feet in diameter, composed of a series of successive layers nearly parallel and perfectly concentric; the layers having a compact texture which are of a dark blue or black color, united by intervening layers of lighter colored calcareous substance either stalactical or granular; they are very thin, more than a hundred in one series. By breaking the matrix they drop out entire. Concentric layers easily separate, leaving the form exactly the same.

Generic and specific characters in this general description are very naturally blended.

Besides shape and minor differences a chief characteristic to be recognized as distinguishing *C. steeli* from *C. proliferеum* is its solitary mode of growth, giving thus individuality to every concentric mass.

The name of this species, *C. steeli*, has been used in manuscript a long time yet without careful characterization. It has also appeared in print in Vol. I., page 504, Bulletin of Geological Society, America, designating a very closely allied specific form collected at Shoreham, Vt., and also observed .elsewhere.

A locality becoming noted these recent years for its fossils is Beekmantown, Clinton County, N. Y.: (so noted that the old designation Calciferous formation slips easily and appropriately into Beekmantown.)

Here at Beekmantown appears a strange though true member of the genus *Cryptozoon.*

CRYPTOZOON SAXIROSEUM. n. sp.

Plates XXXVI, XXXVII, Figs. 3, 5, 6.

A species having the general character of members of the genus, a calcareous, disklike body with fine concentric bands.

These bands are of such peculiar structure and are so characteristic of the genus that they may be denominated Cryptozoal bands. The single elemental structure appears to be a spongy ball, Pila. These balls, Pilæ, may become aggregated and their inviduality lost. In this condition they form the darker portions of the bands. Others are more loosely placed and are separated by irregular channels of varying shape and size. These individual pilæ and the enlarged channels containing them constitute the lighter colored bands.

There is no sharp division between the bands, no laminations. Perhaps these may be an incipient attempt at alignment of the pilæ, but the alternations are the result of dense packing in one case and the more free distribution in enlarged passages in the other. This species *C. saxircseum* partakes fully of the minute

PLATE XXXVI.

Cryptozoon saxiroseum, n. s. One fifth natural size.

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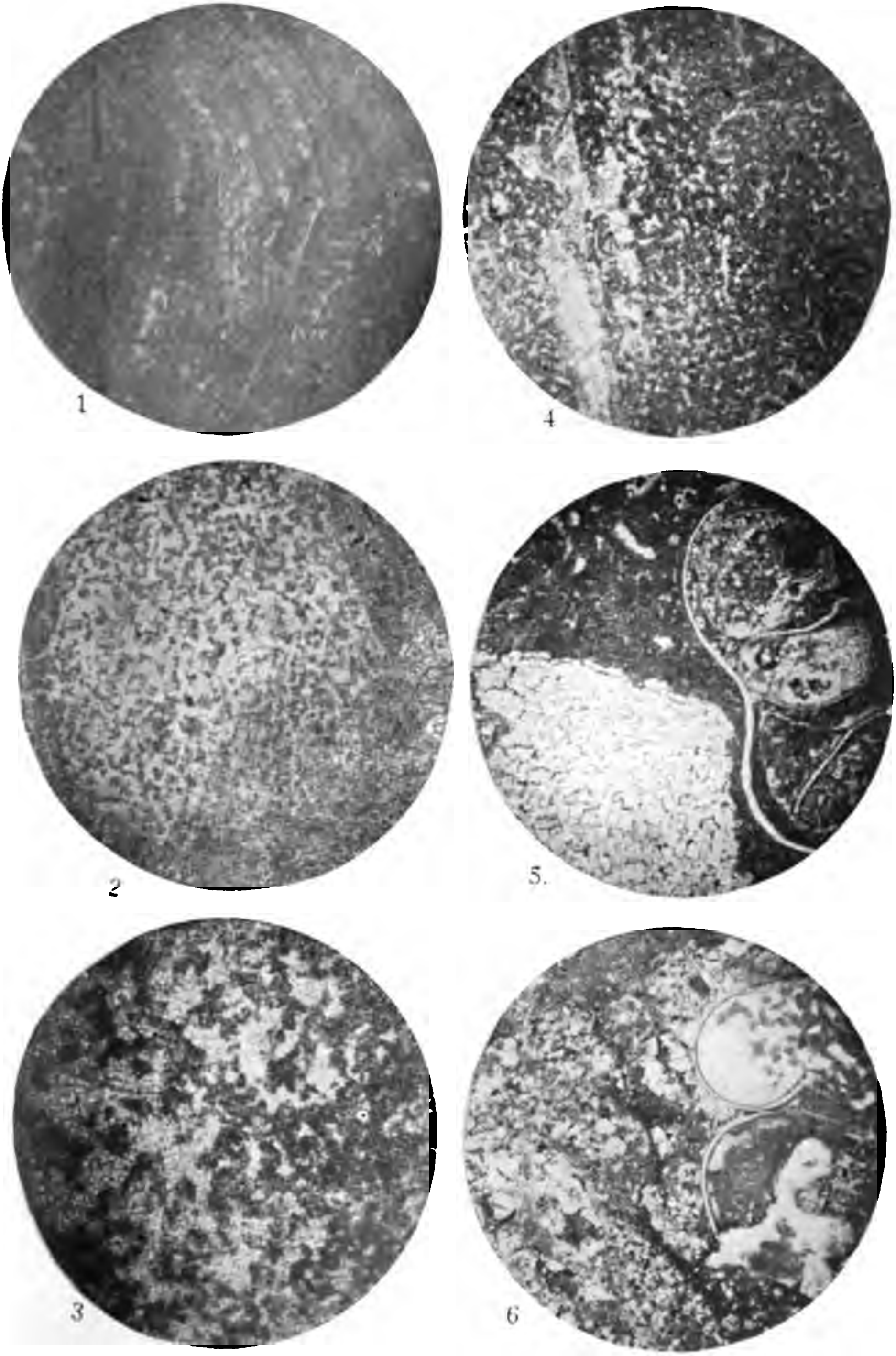
PLATE XXXVII.

EXPLANATION OF PLATE XXXVII.

ALL THE FIGURES ARE MAGNIFIED TEN DIAMETERS.

Figure 1. Structure of Cryptozoon steeli.
Figure 2. Structure of Cryptozoon wingi.
Figure 3. Pilæ in Wingia.
Figure 4. Cryptozoon saxiroseum.
Figure 5. Ovarium and Ova, Cryptozoon saxiroseum.
Figure 6. Another portion of the same ovarium.

PLATE XXXVII.



Photomicrographs of Cryptozoa. Magnified ten diameters.

structure that characterizes the genus. It differs, however, in a marked degree as to manner of growth, and in its advanced stages, in general appearance, from *C. proliferum* and *C. steeli*. In growth it is only by a series of intermediate examples that they are recognized as belonging to the same species. At its young or primary stage it is a typical Cryptozoon, disklike in shape with concentric bands: and so far as observed without pedicle or epitheca. At a succeeding stage the bands away from the centre become interrupted, slightly at first, as though slashed across, then more widely the spaces being filled with subcrystalline matter, then losing continuity the fragments take on a petalous character. The fossil now assumes the appearance of a flower, a central banded disk surrounded by petals, a rose in stone. In examples still further advanced the primary form becomes more and more obscured, the petaloid parts being only observable, and these scattered irregularly through the adjoining fragmental rock. In some cases the rock is largely made up of these detached stone petals. But, however much separated they always retain their original cryptozoal structure.

Years ago the Rev. Augustus Wing found on Mount Independence, Orwell, Vt., a form that he figured in his manuscript as a "Stromatopora," a name long conveniently used for any undifferentiated mass of rounded and banded character. This form obtained and studied proves to be a *Cryptozoon*. It, however, does not fall properly into any of the three species already described. It is so distinct that it is named by itself.

CRYPTOZOON WINGI. n. sp.

Plate XXXVIII.

A discoid very compact form of the genus *Cryptozoon*; in color light, in size usually small, varying from two inches to four inches in diameter, the individuals mostly cohering at the border.

In general appearance it differs from *C. proliferum* especially by each form retaining its individuality; it does not attain the size of *C. steeli* nor does it have the purple tinge; it is easily distinguished from *C. saxiroseum* by the usual coalescence of the borders and the absence of petaloid portions.

STRUCTURE.

Macroscopic..

The descriptions of Steele and Hall previously cited will guide one pretty well in determining this form, *Cryptozoon*. Briefly members of the genus may be described as banded calcareous masses of concentric structure, and of varying size, having the general appearance of concretions. They mostly break freely from the elastic or oolitic matrix, more rarely they show no distinct line of separation.

Stromatoceria and worn masses of like size may call for careful discrimination but a knowledge of horizon and intimate structure will separate them from *Cryptozoon*.

Microscopic.

Plate XXXVII, Fig. 2.

Here again Steele gives suggestions and Hall more definite information as to intimate structure.

Appeal to the microscope often settles doubts. Thin sections of this form have been prepared and used by various observers. The great age of the form and the many possibilities of interstitial change, bid one to be cautious in his conclusions as well as careful in his study.

The observations of many sections of the various species already described leads to the conclusion that the *Cryptozoa* occupy an intermediate place between the rounded sponge like bodies so abundant in the Beekmantown and the *Stromatoceria* of the Chazy formation just above. In the sponges here referred to no continuous canals are observable only irregular broken ones, while in the *Stromatoceria* canals occur with comparative regularity.

Recognition of Pila.

Plate XXXVII, Fig. 3.

The existence of *pila*. A peculiar organic structure, a micros-

PLATE XXXVIII.

Cryptozoon wingi, n. s, reduced one half.

copic spongy ball, is here recognized, but discussion is delayed until the matter of classification is reached.

Ovaria.

Plate XXXVII, Figs. 5 and 6.

In a former examination of the genus *Stromatocerium* in the Chazy formation, certain lacunae appeared, and these peculiar lacunae contained very compact pilae, the structure of which suggested the possibility of their being ova.

In the study of *Cryptozoon* the observation of lacunae with compact globular pilae is repeated. But a difference in character of the lacunae of this genus occurs; they have a more definite shape, that approaching reniform, as well as a more definite boundary, this boundary having apparently been membranous.

The suggestion very naturally arises, and this deepens with continued observation, that each lacuna is an *Ovarium* and the included pilae are *Ova.*

CHARACTER.

The existence of hemispherical or spherical calcareous masses with concentric finely banded laminated structure is conceded. The origin however of these forms may be in question. Are they accidental or are they organic? May they have arisen from concretionary material, the escape of gas as bubbles through soft matter, or from some mechanical though not yet well understood cause?

On the other hand may not they have been produced by the growth of animals of lowly organization?

Some observers have had their doubts as to the organic origin of *Cryptozoa.* Their thought has been expressed mostly by using an emphatic *if*, while referring to this form, saying, "if organic."

Professor Mather, as has been cited, concluded that they were organic. In this opinion Mather has been followed by Dr. Dawson and many others. The character of these forms should not be left longer in doubt. Giving attention to what has been presented and what here follows will there be any room for question?

The occurrence of these named forms at definite horizons, as will be noticed further on, is very significant. Why should they appear among rocks of a given formation, and why crowd layers of a certain horizon of this formation with their peculiar forms? And this in localities far apart! This is certainly the way of organic beings!

The chief appeal however will be to structure. Comparison may be made between thin sections of objects that are confessedly inorganic, such as stalactites, concretions, and the like, and those of well recognized organic origin.

The illustrations, few out of many, presented on previous pages, bear evidence of character other than inorganic. Observation and careful study of these many examples lead one gradually to the recognition of these forms as of organic origin; that the genus *Cryptozoon* now with its various species, was well founded; and that he may confidently rest on this conclusion.

HORIZON.

A brief scheme of the distribution of a portion of the rocks of the Champlain Sea will help to make plain the horizon at which the genus *Cryptozoon* occurs.

The Beekmantown formation is included between the highest division of the Cambrian, C. Potsdam, and the lowest of the A. Chazy.

From lithological or fossiliferous distinction, the formation at its most characteristic localities may be separated into five divisions which, named from the first letters of the alphabet, are A B C D E. These divisions are here used.

FORMATION.	DIVISIONS.	SPECIES.	LOCALITIES.
CHAZY.	A		
BEEKMANTOWN.	E		
	D	*Cryptozoon.*	E. Beekmantown, N. Y.
		C. saxiroseum.	
	C		
	B	*Cryptozoon.*	Shoreham, Vt.
		C. steeli.	
		C. wingi.	Mt. Independence, Vt.
			Fort Ann, N. Y.
			Colchester, Vt.
	A		
POTSDAM,	C		

LOCALITIES.

The distribution of these forms in the east is apparently within the borders of the early Champlain Sea.

The localities of *Cryptozoon proliferum* following Hall are Greenfield and Little Falls, N. Y.

The original stations of *Cryptozoon steeli* as indicated by Steele are between Greenfield and Ballston Spa., N. Y. To this first station several are to be added. One is on the farm formerly occupied by B. Chenette, Shoreham, Vt. The *Cryptozoa* here, like those described by Steele, rest upon oolitic rock. Beautiful large examples have been obtained. These have the purple tinge of the forms earliest noted. The agate like bands however do not separate from each other readily but by a blow break across with a shining conchoidal fracture.

Cornwall also furnishes this form. And another station is Phillipsburg, Canada. Going north along the highway from the United States boundary line, some most notable examples have been seen in the rock by the roadside.

So far as is known to the writer *Cryptozoon saxiroseum* has but a single station, that of East Beekmantown, Clinton County, N. Y. This genus here adds another form to the locality so fossiliferous that the old time term Calciferous slips easily and appropriately into Beekmantown. Thus far it has been obtained only from bowlders and detached pieces of rock. These however contain at times Ophileta and characteristic fossils such as are found in a nearby low ledge. Some examples have been observed in the tumble down disappearing walls of a mill on Dead Creek. It is to be hoped that a careful collector may be rewarded by a search among the near by rocks.

The primary station for *Cryptozoon wingi* is Mt. Independence, Orwell, Vt. This is across the lake less than a hundred rods southeast from Fort Ticonderoga. The more level part of the top was once a parade ground for the soldiers of the fort. Here on this parade ground Wing in his field notes with a well drawn sketch located a station for his "*Stromatopora.*" And here after a second day's search the exact place of a few square feet was found. The fossil is evidently a *Cryptozoon* though unlike any before observed. The horizon is plainly B. Beekmantown.

Another station is awaiting the careful search of the persevering collector in the town of Fort Ann, Washington County, N. Y. An example in Wing's collection is briefly marked "Concretionary Limestone, Comstocks, N. Y." Sectionizing revealed its organic origin. Duplicates with exact locality and real horizon were worth finding. A long day's search showed an abundance of B. Beekmantown and many obscure fossils but failed to yield the desired *Cryptozoon*. Yet the fossil is there waiting only to be recognized.

Still another station is Colchester, Vt., a locality which has yielded Professor G. H. Perkins, State Geologist, many interesting fossils. Here is probably the most promising ground for the collection of this species. Other known localities have been practically exhausted.

POSSIBLE LOCALITIES.

Localities yet unobserved probably exist. The collection of the *Cryptozoa* for the most part hitherto has been incidental. Special search should be made. With a knowledge of the horizon and the usually associated rocks the finding of new stations may be confidently predicted. Especially should they be looked for wherever the oolitic strata of the Beekmantown are exposed. Nor should search be confined to the immediate vicinity of the present Champlain Valley but the form may be looked for within the former extension of the early Champlain Sea extending as far south as Franklin, Bergen County, N. J.

Just here may be briefly noticed forms of *Cryptozoa* which have not come under the writer's own observation.

In the Canadian Record of Science Vol. VII. No. 4, pp. 203 ————Sir William Dawson publishes "A Note on *Cryptozoa* and other Ancient Fossils" in which he describes and figures certain *Cryptozoa*. The names and localities are here given:

Cryptozoon lachutense. n. sp.

Lachute, P. Q. Beekmantown formation.

Cryptozoon boreale. n. sp.

Lake St. John, P. Q. (Trenton formation.)

Cryptozoon occidentale. n. sp. Collected by Walcott. Grand Canyon, Arizona. (Pre-Cambrian.)

A careful revision of the second and third numbers here given would very likely place them in some other genus, as they go wide of the horizon in which other *Cryptozoa* have been found.

One could easily wish that Professor Mather had made his localities more definite. When speaking of Steele's forms he contents himself by saying similar masses have been observed in the Valley of the Mississippi particularly in Missouri and Wisconsin.

The existence however of *Cryptozoa* in the middle west is assured by the discovery in Shakopee formation by Professor N. H. Winchell of a form of this genus though differing somewhat in mode of growth from the type species. This was named by Professor Winchell *Cryptozoon minnesotense*, n. sp., and was described and figured at p. 313 in his 14th Annual Report of the Geology of Minnesota.

Professor L. W. Chaney of Carleton College, Minnesota, has described a form of remarkable size found by him also in the Shakopee formation. (This above the Cambrian) and this he tentatively named a *Cryptozoon*.

Cryptozoon americanum. n. sp.

magnificum ?

Gathering up the names and localities of the described *Cryptozoa* there stand these:

Cryptozoon proliferum. Hall. Greenfield, N. Y. Little Falls, N. Y.

C. steeli. n. sp. Greenfield, N. Y. Shoreham, Vt. Philipsburg, Canada.

C. saxiroseum. n. sp. Beekmantown, N. Y. Grand Isle, Vt.

C. wingi. n. sp. Mt. Independence, Vt. Colchester, Vt. Fort Ann, N. Y.

Here follow Dawson's Species.

C. lachutense. Dawson. Lachute, P. Q. Canada.

C. boreale. Dawson. Lake St. John, P. Q. Canada.

C. occidentale. Dawson. Grand Canyon, Arizona.

From the Middle West:

C. minnesotense. Winchell. Shakopee, Minn.

C. magnificum? Shakopee, Minn.

RELATIONSHIPS OF THE GENUS.

The appropriate place of the genus in the system of classification is a matter of interest. "Many times have passed over" the fossil, many possibilities of interstitial change have existed so one is bidden to proceed with caution. Observers will see these forms from the point at which they themselves stand, so divergence of views may be expected.

This may be safely said of *Cryptozoon*; its place is between the abundant sponge like forms of the Beekmantown and those of the *Stromatoceria* of the Chazy; the former with its broken or irregular canals, the latter with canals of comparative regularity.

CLASSIFICATION.

The further study of the low fossil forms placed with the Sub-Class *Calcispongia* has brought into notice new members of the group. Seeking a place for them in classification they are found to fall quite outside of any of the described orders. None of the existing orders will admit them. Yet they are very distinct. They have a character of their own and they properly demand recognition. In a system of classification a place must be sought for them.

A structural relationship may be looked for on which the new order may be based. Fortunately a distinct structure has been observed and traced through quite distinct genera; this structure constant and essential to all. This relationship of structure will band these allied genera into a natural order.

This order may be named EOASCONES.

It may help to a clearer understanding of the character of this order if a term and a definition be introduced here. Pila. Ball.

Pila is defined as a ball, or tassel like mass, the individual basal structure of the *Calcispongiae* included under the order *Eoascones.* This globular mass has a close resemblance to a minute compressed sponge. The diameter as seen in *Cryptozoa* varies from .125 mm. to .50 mm. in diameter. While free and unmodified it is nearly spherical, but pressed by aggregation of numbers it takes on an elongated or other secondary form.

It is well displayed in what appears as the lighter bands or laminae of the concentric structure of the *Cryptozoon.* These lighter bands seen in the microscopic field seem sown with individual pilae. More compressed however the pilae mass together leaving among themselves those irregular canals which so characterize the organic structure of the *Cryptozoa.* By greater compression the pilae lose their individuality and appear a more compact mass, yet in the main retain their spongy character.

EOASCONES. new order.

Eoascones, an order of calcareous sponges mostly spherical, rarely discoid or turbinate, canals irregular or indistinct, with or without laminae, the essential structure being of pilae.

Found thus far in the Beekmantown, Chazy and Black River rocks.

The order includes the genera *Eospongia. Stromatocerium, Cryptozoon, Strephochetus,* and *Wingia*; all of which are pilae bearing. It probably includes forms which have been characterized as of "curdled" structure. It separates sharply *Stromatopora* which is found in the Devonian from the two genera, *Cryptozoon* and *Stromatocerium* that have been confused with it.

FAMILY.

STROMATOCERIDAE. New Family.

Stromatoceridae. Characterized by a very pronounced banded structure this structure varying from a mass of loose balls, pilae, with scarcely noticeable arrangement, to the most complete alignment of these pilae into compact concentric or rarely tubercular or tabular growths. No regular series of communication exist between the bands of laminae, circulation having been apparently through minute pores.

The family is separated from the *Strephochetidae* by the absence of the twining canals of the latter; from the *Stromatoporidac* by the absence of the radial pillars which connect laminae such a prominent characteristic of this family, which also has been described as found at a much higher horizon.

CLASSIFICATION.

The following provisional scheme is here exhibited as one giving *Cryptozoon* an orderly place in the system of classification.

Sub-Kingdom	Coelenterata
Sub-Branch	Porifera
Class	Spongia
Sub-Class	Calcispongiae
Order	Eoascones
Family	Stromatoceridae
Genus	Cryptozoon
Species	C. proliferum
"	C. steeli
"	C. saxiroseum
"	C. wingi
"	Others

CONCLUSIONS.

Upon the surface or along the borders of the upper Cambrian rocks was laid anotber formation of rocks of various kinds, some siliceous, others mixed siliceous and calcareous, still others combined calcareous and magnesian and a few purely calcareous.

A portion of this old time sea producing these rocks may be delimited as sweeping in an irregular crescent from Atlantic back to Atlantic through the depression of the St. Lawrence, broadening at Lake Champlain, then narrowing and reaching the ocean through the Hudson Valley.

To the water making the semi-circuit the title is given, the Early or Eochamplain Sea.

In these waters sea plants grew; and animals of every known type but one, found here their home.

Among the lowly forms of animals growing in the shallower waters was one increasing by concentric laminae producing a rounded calcareous mass. On the stony remains of this animal we engrave this memorial name, *Cryptozoon*.

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Beekmantown and Chazy Formations in the Champlain Valley, Contributions to their Geology and Paleontology.

H. M. SEELY.

---

1. THE WING CONGLOMERATE; AND 2. WINGIA.

The Vermont Geological Survey left a large question to be answered when the marbles and limestones of Western Vermont were bunched, and were named "Eolian limestone."

The Eolian limestone what? What its age? What its equivalents? To answer the complex question the Rev. Augustus Wing in the late sixties and early seventies gave years of his life; and his accepted reply in effect was, that the Eolian limestone is a mass name for the calcareous rocks between the sandstone of the Potsdam below and the layers of the Utica Slate above. And these equivalent rocks were those recognized at that time as the Calciferous, Quebec, Chazy and Trenton formations.

One of the most satisfactory fields of Wing's study was a portion of the town of Shoreham, Vt., where the rocks by their stratification and fossils revealed to him their true character. Among the strata named and emphasized in his notes were the "Ophileta beds" the "Trilobite bed" and the "Conglomerate bed." This "Conglomerate" to which special attention is to be directed was placed by Mr. Wing in the Quebec Group just above his Ophileta beds of the Calciferous.

The Quebec group having disappeared from geological literature, and the Calciferous formation having found a more recent equivalent in the term Beekmantown, a new question arises;

What the horizon at which Mr. Wing found the "Conglomerate bed?" A second question naturally follows and this; What the character of this conglomerate?

Leaving the second question for later consideration we may give ourselves to answering the first. That the beds named belong to the formation where Mr. Wing placed them, that is in the Calciferous according to the geological language of his time, has been fully proved by the discovery of abundant fossils of *Ophileta complanata* in the rocks of East Beekmantown, N. Y. the deposit here being so rich in this and other forms that the locality has given its name to the formation displacing Calciferous by Beekmantown.

The fact that the rocks of the Beekmantown have in some cases a thickness of 2,000 feet leaves the exact horizon of the conglomerate still uncertain.

DIVISIONS OF THE BEEKMANTOWN.

Additions to our knowledge of the little that was known of this formation at the time of Mr. Wing's explorations and observations have indicated that the rocks of the Beekmantown may be distinguished into five Divisions, A B C D E, counting upwards from A; these divisions based on the character of the rocks and their contained fossils.

For discussion of the Beekmantown fossils and divisions of rocks the reader is referred to the early volumes of the Bulletin of American Museum of Natural History, particularly in reference to the division here cited to Vol. III, pp. 2-3. 1890.

It is very well established that the Ophileta bed of East Beekmantown is contained in the lower part of Division D, that is the fourth of the ascending series of the five divisions.

LOCALITIES OF CONGLOMERATE BED.

The conglomerate has not been recognized at the top of the Ophileta bed at Beekmantown. In Shoreham it has been found at least at two localities. On Providence Island, Lake Champlain, there is a bed like those of Shoreham. At Ball's Bay, Ferrisburg, Vt., also is found a deposit of conglomerate and this at the horizon of those at Shoreham.

HORIZON.

The associated rocks whose horizon can be clearly made out enable one to pronounce with emphasis the horizon of the conglomerate bed, and so it is determined to be near the top of Division D, Beekmantown.

CHARACTER OF THE CONGLOMERATE.

The exact thickness of the deposit is not stated; that it exists in force however is asserted. Careful examination is still needed to determine this point.

In description of its more particular properties the essential part of the original statement reads: "A conglomerate made from flat and rounded pebbles from the quartzite below, the flat ones one or two inches across, the rounded ones from coarse shot to large bullets; the paste a limestone."

A partial description by another hand reads; "The lime stone often appears to be a conglomerate, the small nodular pebbles being somewhat angular and arenaceous."

Here then is described a limestone rock in the D Beekmantown a portion of which is like a conglomerate while the source and character of the fragments are at least partially indicated.

The observations of the writer as to the character of the conglomerate have been confined mostly to examples collected at Balls Bay. But the horizon and general appearance of the rock correspond with that of Shoreham and evidently they are portions of the same formation.

SPECIAL CHARACTERISTICS OF THE CONGLOMERATE.

Plate XXXIX.

The wide spread occurrence of such similar material is notable. At points fifty miles apart the same forces have been at work. Similar results have been attained. Was it really by the breaking of the rock and rounding of fragments that these discoid and spherical masses had their origin? The associated deposits seem to have been laid down in quiet waters. The flattened species as described by Wing stand on edge and at all angles. It is difficult to imagine how in either swift or slow running waters these portions would be laid together as they are.

ORIGIN OF THE MATERIALS OF THE CONGLOMERATE.

Now while it is too early in the investigation to assert that there are no quartzite or arenaceous pebbles in the conglomerate it is to be said that many of the subangular and spherical masses which simulate pebbles in size and appearance have the smooth uniform surface that appears in a *Solenpora* or the fine lined *Prasopora*. Thin sections under the microscope however do not give the structure of *Solenpora*, *Prasopora*, or any allied genus. Yet the structure is plainly of organic origin. Observations have been so many times repeated that the writer is forced to the conclusion that he has been dealing with a fossil and not with an inorganic mass.

INDIVIDUAL STRUCTURE.

The structure, though pronounced, is unlike any previously examined. It seems made up of tufted balls or pilæ, these indiscriminately mingled without the suggestion of regular or broken canals as found in the *Stromatoceria* or *Cryptozoa*.

AN UNDESCRIBED FOSSIL.

From among the pebbles, concretions, and obscure lowly organisms, notably abundant in the Chazy and Beekmantown and as notably confusing, there emerges a definite though lowly fossil form. Its structure is so evidently organic that it cannot be left with pebbles or concretions.

RELATIONSHIPS.

As one goes down in the rocks, and back in time, away from existing animal forms, he need not be surprised that the archaic form does not drop readily into any previously arranged scheme of classification. Often the early forms must be grouped provisionally with the expectation that later observation will confirm or correct the assumed classification. Such tentative classification and suggested relationships are here offered, as also generic and specific names.

The newly observed form is thought to fall within the recently erected order, EOASCONES. It may belong to a family of its own to be named subsequently.

No existing generic name has been found to fitly characterize the new fossil. A new one must be sought. Keeping in mind the good service done for science by the one who first pointed out the conglomerate no more appropriate name for the new genus can be found than the one here proposed.

II. WINGIA: A NEW GENUS OF BEEKMANTOWN SPONGES.

A calcareous fossil sponge, with or without silicious spicules, spherical nodular or discoid; from 1 cm. to 10 cm. in size; the essential structure a collection of pilæ or tufted balls, these mostly .25 mm in diameter, massed without definite arrangement or rarely more loosely distributed through the containing calcite.

The fossil has thus far been found at a single horizon but it is probably more widely distributed; this horizon near the middle of division D Beekmantown, in Shoreham, on Providence Island, and at Ball Bay, Vt. The illustrations, microscopic and macroscopic, are from examples collected near Ball Bay.

WINGIA CONGREGATA n. sp.

Plate XXXIX.

This, the typical species, bears the special structure of the genus, that of indefinitely intermingled pilæ massed or more widely distributed; spherical or subglobular; from 1 cm. to 4 cm. in diameter, the individuals in the main closely compacted, but in ascending rock more loosely aggregated, more spherical, and of greater size.

PLATE XXXIX.

Wingia Conglomerate containing W. congregata and W. discoidea. One half natural size.

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PLATE XL.

Wingia lapilla, n. s. natural size.

Pores or special external characteristics so far as yet observed are wanting.

As noted in description of Genus, horizon is D Beekmantown; localities, Shoreham, Providence Island, Ball Bay, and Fort Cassin, Vt.

Plate XXXIX. The conglomerate contains *Wingia congregata* and *W. discoidea.*

WINGIA LAPILLA. n. sp.

Plate XL.

The species *Wingia lapilla* differs from the typical species *W. congregata* in size, average examples being 10 cm. in diameter, in shape being nodular or irregular, in composition being rich in silicious specules.

Its position seems to be higher in the strata than *W. congregata* and it occurs sparsely distributed in the calciferous rock.

WINGIA DISCOIDEA. n. sp.

Plate XXXIX.

A very distinct member of the genus, *Wingia discoidea*, is discoid in shape and on weathering shows a granular striated surface.

The position is low down in the *Wingia* bearing rock, the mass wonderfully simulating an arenaceous or slaty conglomerate.

III. LIMITING LAYERS OF THE CHAMPLAIN CHAZY WITH NOTICE OF THE ISLE LA MOTTE SANDSTONE.

The rocky boundaries of the Chazy formation may be characterized as roof and floor; the roof Black River, the floor Beekmantown.

The roof Black River, is often associated with the Trenton as the lowest member of this formation. It is of itself a subject worthy of special study. Briefly it may be mentioned as a wide spread rock of such peculiar character that usually it may be readily distinguished from the wider and overlying formations, rich in carbonaceous materials, and abounding in fossils. Besides the eminently characteristic fossils *Stromatocerium rugosum* and *Columnaria alveolata* there are found in the layers many bryozoans, brachiopods, and mollusks. Among the latter are Maclureas particularly *Maclurea grandis* and enormous straight chambered shells.

In many localities the Black River extends beyond the limits of the Chazy as a cornice of a house may extend beyond the house. In rare instances even in the Champlain Valley as at Larrabees Point it rests directly upon the Beekmantown, the Chazy being entirely lacking.

This much of the roof or upper limit of the Chazy.

The floor, the foundation on which the Chazy is laid, is more extensive and at the same time the rocks are more massive. Of the five divisions into which the Beekmantown may, for convenience of study, be separated, the upper or E Beekmantown only concerns us here, and of this only the upper part. Of this upper part three varieties of rock are noticeable at various exposures; one, a tough blue magnesian limestone containing many named and unnamed gasteropods, ostracods and trilobites; a second, a silicious limestone of flinty texture characterized also by ostracods; and a third, a tough gray magnesian limestone, breaking in angular blocks, which on weathering show their content of iron by the appearance over their surface of a wash of ocher. This last peculiarity enables one to distinguish the rock at a distance.

Upon this varying mass of upper Beekmantown, but more largely upon this latter ferruginous limestone, was the Chazy laid down. Just what then occurred in the early Champlain Sea it may be difficult to determine. But this may be safely asserted; there was an upward movement from the bottom. In some of the deeper parts the old conditions may have largely prevailed, and a deposit of former character continued. But largely new shore lines were produced and along these lines new conditions prevailed. Previously existing forms of life disappeared. Waves and currents brought from abraded rocks the broken down material and distributed this along the shore. So here and wherever the depth of water favored, a sandy deposit, later to be hardened into firm rock, was laid down.

IV. ISLE LA MOTTE SANDSTONE.

It was under such conditions the Isle La Motte sandstone was produced. Upon the Beekmantown floor with its billowy surface the first distinct Chazy stratum, the basal rock, was deposited. Shore, off shore, and places of moderate depth of water, received this accumulation of broken material, chiefly a rich ferruginous sand.

And this now is a firm rock. Exposures of this sandstone are exhibited on Vermont islands and shores. Those at Field Bay, South Hero, and Isle La Motte, are most noticeable. Particularly at the Head on Isle La Motte, the rock shows itself in cliff-like force nearly twenty-five feet in thickness. So notable is this in character that the whole deposit may properly bear the name here used, the Isle La Motte sandstone.

Other strata of sandstone do indeed occur in the Chazy but they are local, rare, insignificant in thickness, and differing in many particulars from the Isle La Motte sandstone.

A fossil characterizing this sandstone is the beach loving Lingula. A particular species, described as *Lingula limitaris* on a nearby page, is very abundant in some layers; so abundant in the So. Hero locality that the rock it largely fills might properly be termed a Lingula sandstone.

It is true that the Isle La Motte sandstone is the basal rock of the Chazy. But it must not be inferred that it is so without exception. In rather rare localities the line between the rocks of the two formations is in no way a distinct one. One may confidently assert that this rock here is Beekmantown, and this a few feet higher up as certainly Chazy. But a line drawn separating them would be an arbitrary one. So the Beekmantown may shade into the Chazy without any sharp definition.

This may probably be best accounted for by a supposition already presented; at the period of the uprise of the Beekmantown bottom there existed away from the shore deep places or bays where the change at first was little felt, and the previous conditions of deposit continued for an indefinite time. The deposit itself would partake of the characteristics of both formations.

It is with this basal layer of the Chazy and equally with the highest that we are at this time concerned. Yet a passing glance as we go from the lowest to the highest strata will be instructive.

In certain localities one need not go high up to reach the massive crinoidal beds, with their red dots, and the strange little *Bolboporites* which when sawn form the elegant Lepanto marble. The Orthis layers have in time past been the source of a lime burning industry. Stromatoceria corals, delicate bryozoans, univalve mollusks as *Raphistoma*, *Scalites*, *Metoptoma*, and the like, mark certain layers, while cepalopods and trilobites reveal what was once the population of this sea.

If we call this portion division A, just above in division B we shall find massive layers which have made the Chazy commercially noted. From these layers the Isle La Motte limestone has sent out for over a century marble like blocks much demanded for construction, and particularly for sawing into floor tiling. Within these squares of tiling will frequently be seen sections of the coiled *Maclurea magna* the most known characteristic fossil of the Chazy and also with it the massive *Stromatocerium lamottense*.

Above this division B comes C the third and uppermost, not distinguished indeed by its valuable quarries but notable for the wealth of its fossil forms. Sponges, corals, bryozoans, brachiopods, univalves, chambered mollusks straight curved and coiled, and trilobites, all found their homes in the waters of this old time sea. Whole layers, as certain portions of the Rhynchonella bed, are made of the hard remains of these animals.

The uppermost rock and fossil.

Coming now to the upper limit of the Chazy one would gladly find a stratum or layer as prevalent as is the sandstone at the base. Few opportunities for accurate determination occur. But in most cases seen there is a strange duplication of what is found in the uppermost layer of the Beekmantown; a magnesium limestone, which in color and fracture so resembles the mentioned rock that in labeling a hand specimen one must be guided by the association rather than by the eye. In rare instances there occurs a thin layer of sandstone over the limestone; but probably this may be regarded as exceptional.

PLATE XLI.

Lingula limitaris, n. s. Slightly enlarged.

No fossils so far as known to the writer have been recorded from the sandy layer. The highest fossil found has appeared most likely in the magnesian layer. Here has been observed the *Solenopora compacta*. This form at times appears so abundant as to make the rock apppear like a conglomerate with a little amount of paste holding the small masses together, at others the fossil is very sparsely strewn through the body of the magnesian stone.

This fossil Billings describes, though under another name, as coming from the Black River. Others have found their abundant examples in the Trenton. As far, however, as present observation goes it is absent from both the Black River and Trenton in Vermont, but is characteristic of the highest layer of the Chazy.

The Chazy formation as here shown has these limits; it begins in most cases with a sandstone, its fossil a lingula; it ends in many cases with a magnesian limestone, its fossil a Solenopora.

V. LINGULA LIMITARIS. n. sp.

Plate XLI.

Shell subovate, length 32 millimeters, greatest breadth 22 millimeters, apex acute, length of apex to shoulder 10 millimeters, breadth at shoulder 15 millimeters: from the shoulder the borders slightly diverge until they reach the breadth above noted, where they round gently and then form a straight anterior border.

The valves near the shoulder are markedly convex, but convexity diminishes near the anterior border. The surface is smooth and shining, the still existing carbonized valves being in most cases jet black. Lines of concentric growth are quite evident, though not pronounced except where exfoliated, when the anterior portion is notably rugose. Radiating striæ are evident though minute, these appearing most plainly on the anterior half of the valve. These radiating lines are more distinct on the interior of the valves; muscular scars scarcely observable.

This, one of the few Lingulæ of the Chazy, holds an unique place marking as it does the basal part of the formation. It has been long known in field work and in manuscript notes. The name has appeared incidentally in print, but the form has awaited description.

Horizon. As above stated the fossil is found at the base of the Chazy.

Occurrence and Localities. Wherever the basal sandstone occurs this Lingula may be looked for, as at Field's Bay, Ferrisburg, Vt., at the Head, Isle La Motte, Vt., and at South Hero, Vt., where it is beautifully displayed just above the magnesian Beekmantown rock.

VI. MONTICULIPORA.

The American Bryozoa are known to have been well developed as early as the upper part of the Beekmantown formation. Their earlier existence may be confidently looked for. The genus *Rhinopora* seems at present to have been the leader of the host that in later formations became so great. It was found in the rocks at Fort Cassin, Vt., and these rocks by comparison with others bearing like fossils are recognized as belonging to the horizon of division D of the Beekmantown.

In the Bulletin of the American Museum of Natural History, Vol. IX, p. 177, 1897, Professor R. P. Whitfield described an early, perhaps the earliest known, bryozoon under the designation of *Rhinopora prima*. This well developed form indicates associates, in the same rocks and those of the same horizon, and points to ancestors below.

Plate XLII reproduces the original figure mentioned above.

Turning from the disappearing forms below to the incoming Gad of the strata above it is found that the Chazy affords in all of its three divisions abundant examples of bryozoa, from the delicate and frond like forms of division A, to the compact almost massive examples of division C.

It is the purpose of the writer to present here one of these compact forms. It has incidentally appeared by name in notes on the Chazy, but so far as known has not been described. This is to be known by the name here given.

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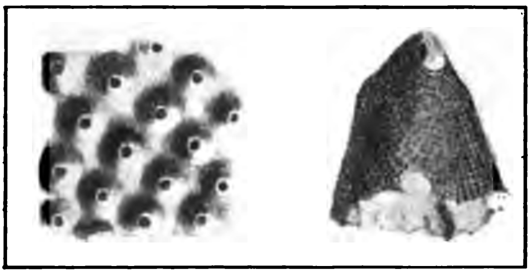
PLATE XLII.

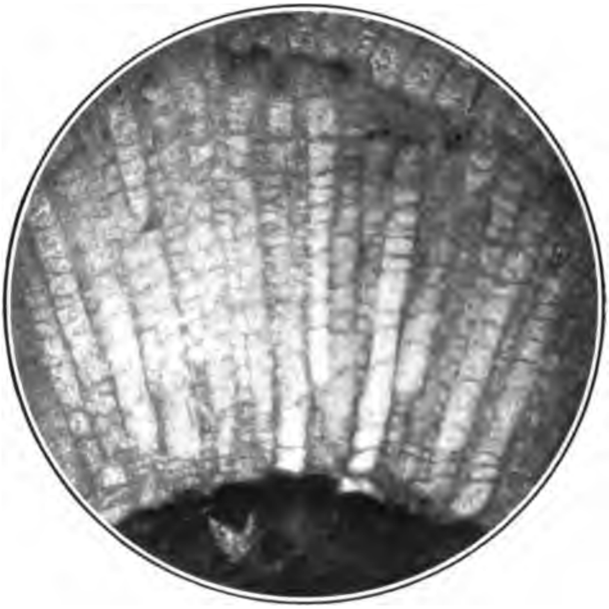


Rhinopora prima after Whitfields Figure.

PLATE XLIII.

Monticulipora insularis, n. s. Natural size.

PLATE XLIV.



Monticulipora insularis, n. s. showing mode of growth story above story. Magnified ten times.

MONTICULIPORA INSULARIS, n. sp.

Plates XLIII and XLIV.

A nodular very compact fossil varying in size from 6 cm. to 22 cm.; made up of closely packed tubes standing in layers or stroma upon similar concentric stroma, with appearance of story built above story. The polished surface resembles map lines as drawn about an island, a weathered one like the section of a *Stromatocerium*.

Rarely a shell forms a core around which the layers have been arranged. Occasionally shells have been included and engulfed in the stroma of the enlarging form.

The tubes standing together forming the stroma are on the average 10 mm. in length and the polygonal individual tubes are .50 mm. in diameter.

Horizon. The fossil is found very near the top of C. Chazy in the *Rhynchonella* beds.

Locality and occurrence. Thus far the locality is confined to South Hero, Vt. Along the shores of Lake Champlain south of Eagle Camp where the water acts upon the strata containing this form, the nodules loosened by the waves drop down into the water.

At a ledge in a field inland near Landons, weathering has brought out fine sections of the fossils showing beautifully the structure which so much resembles a *Stromatocerium*.

A rounded mass, much larger than a man's fist, covered and disguised by a thin film of the matrix from which it had fallen, would hardly suggest the presence of a *bryozoan*. Exposed however for a time to favorable weathering, the outer ends of the tubes reveal the fossiliferous character of the mass, which later study assigns to its proper place and relationship.

And again a natural section of the size of the palm of a man's hand made by the weathering of an object in a cliff, with stroma above stroma, is at first sight very misleading. But study reveals the fact as before, that the object is a *bryozoan*, and further that it may appropriately bear the name here given, *Monticulipora insularis*.

VII. PRASOPORA.

The puff ball form of this genus so characteristic of the rocks of the Trenton is found from bottom to top in the formation in Vermont. Some layers are so crowded with the fossil as to produce continuous sheets which when broken up form small bowlders.

Early recognized, early described and pictured, it has passed under several generic names. However it seems now to have come to an undisturbed rest under the designation of *Prasopora lycoperdon*. Generally so uniform in structure it is easily detected; a low dome or sharper cone which in very rare cases branches, its coarse tubes .50 to 1. mm. in diameter standing upon a wrinkled epitheca, this in shape like the bottom of a glass junk bottle forms a conspicuous object in the rock.

The number of described species of the genus is not far from twenty these being mostly found in the Trenton or equivalent rocks.

Relationship. The relationship of the genus is fairly represented in the following scheme.

SUB-KINGDOM V. MOLLUSCOIDEA.

Class I . . . . *Bryozoa* . . . . Ehrenberg
Order I . . . . *Gymnolæmata* . . . . Allman
Sub-Order B . . . . *Trepostomata* . . . . Ulrich
Family I . . . . *Monticuliporidæ* . . . . Nicholas
Genus . . . . *Prasopora* . . . . . . Nicholas and Ethridge

The members of the genus *Prasopora* have, as noted, been heretofore described as coming from the rocks of the Trenton formation. The genus however had an earlier existence. Within a little time past it has been collected by the writer from the underlying formation, that is the Chazy.

As readily anticipated the character of the form would differ from the overlying later ones. And so it is. To the species already recognized there is now to be added another, gathered at a new horizon, and bearing distinct characteristics. This is designated :

PLATE XLV.

Prasopora hero, n. s. Somewhat reduced.

PRASOPORA HERO. n. sp.

Plate XLV.

The fossil *Prasopora hero* consists of a lenticular calcareous mass of varying size and shape ; usual outline oval sometimes however much elongated ; its lower surface rounded or boat shaped. An example of medium size measures 100 mm. by 50 mm. with a thickness of 35 mm. Epitheca not well defined. The form in the rock appears like a concretion, scarcely with evident structure until microscopic enlargement, when it exhibits tubes varying in diameter from .20 mm. to .50 mm., these showing distinctly the characteristics of the genus.

Horizon. Thus far *Prasopora hero* has been observed only at the horizon of the *Rhynchonella* beds, that is in the upper part of C Chazy.

Locality. Shore of Lake Champlain, south of Eagle Camp, South Hero, Vt.

Distinctions. The nearest neighboring *Prasopora* is *P. lycoperdon* in the formation above, and from this form, the horizon, the shape and especially the diminutive tubes, will widely distinguish the Chazy *P. hero*.

The Lignite or Brown Coal of Brandon.

SECOND PAPER. G. H. PERKINS.

In the Report of the State Geologist immediately preceding this, there is an extended account of the very peculiar and interesting deposit of lignite which is located in the town of Brandon.

It is, of course, needless to repeat here the facts given in the previous paper, but it may well be read by those who desire fuller acquaintance with the history and past study of the deposit, as well as its geological relations. In the above named paper 118 species are described and most are figured. Of these 20 are recognized as described, mostly by Lesquereux, the remainder are considered as new. A sketch map of the immediate locality, drawn by Professor T. N. Dale, was also shown. This is reproduced in the accompanying figure.

About a year later, December, 1905, the writer published in Bulletin 21, of the Geological Society of America, pp. 499-516, Plates 86 and 87, a resume of the account in the Geological Report with such additions as had been suggested by further investigation. As these two plates show examples of the more important species described in the report they are repeated in Plates LII and LIII which follow the paper in this volume on the lignite fossils.

Since these publications were issued, renewed investigation of the locality and study of the fossils has furnished new results which are given in the following pages. Unfortunately, very little fresh lignite has been dug during the last two years, but some previously overlooked piles were found and a considerable number of specimens were obtained from men who had formerly worked in the deposit and had from curiosity preserved some of the fruits which had come under their notice. In this way quite an amount of new material was acquired.

The Brandon lignite is quite peculiar in character and appearance. I have examined lignite from many localities in different parts of the world, from Disco to New South Wales, but have seen none that was exactly like that found in Brandon. In

Fig. IV.

Map of a part of Brandon showing location of lignite. Contour interval 20 feet. Topography by U. S. Geological Survey. Cv-Cambrian quartzite and schist. Dark area-lignite, kaolin, and limonite.

most cases the lignite is much more completely carbonized. It is black, brittle and is in appearance much like coal, while the Vermont lignite does not usually resemble coal, at all, and is not usually black, but is more like compact, partly decayed wood, but is always much more solid than that. In those cases in which it is black, the Brandon lignite is more like jet than coal.

Although any illustration of this material is necessarily only a quite imperfect representation of the actual substance, yet as no illustrations have ever been published, I have introduced the four which follow this paper as showing four of the most commonly found varieties. Figure 5 on Plate LVIII also shows another common variety.

In some specimens of what is labelled "Fibrous Lignite" which I find in our museum, there is substantially the same structure and the appearance is more similar to that of the Brandon lignite than others which I have seen. This "Fibrous Lignite" is from Restadt, Eisleben. To what geological period it belongs, I have not been able to discover. The most coal-like lignite found in Brandon is from the most southerly shaft and this is not unlike what is called "Lettenkohle" which is found in the Keuper at Gaildorf, Wurtemburg. We have also some lignite from South Africa in which the grain of the wood is well preserved, and this too somewhat resembles that of Brandon. In our lignite there is considerable variety in structure, appearance and density. Some of it, as the piece shown in Figure 2 of Plate XLVI, shows the woody fiber very distinctly, more so than was seen, probably, in the fresh wood. Indeed in such lignite as is shown in all the pieces on Plates XLVI and XLVII there is no difficulty in making out the original woody structure, though it is more distinctly seen in some than in others. Nor does there seem to have been very much compression or distortion in most of it. From these less changed forms there are numerous stages, until finally, there is that which shows no woody structure, but is little more than a mass of highly carbonaceous material.

The specimen shown on Plate XLVIII, Figure 5 is of this sort.

Of course fossils are not found imbedded in that lignite which has undergone so little change that the woody fiber remains distinct. All the fruits occur in the amorphous sort. In the figure last named there may be seen near the upper border a hemispherical cavity from which a globular fruit has dropped.

There appear to be two distinct beds of the lignite. It is all obtained, as stated in the previous paper, from shafts sunk to

PLATE XLVI.

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2

Brandon Lignite.

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PLATE XLVII.

1

2

Brandon Lignite.

obtain a fine kaolin, the lignite being only an incidental product. Nearly all that has been obtained for years has come from two shafts, or from drifts running from them. Although these shafts are not more than six hundred feet apart, yet the material taken from them is quite dissimilar. That from the north shaft is variable in color, structure and density, but none of it is exactly like that from the south shaft and most is quite unlike it. This is all uniform in character and has never afforded any fossils. It is harder, blacker and more brittle.

There does not appear to be any connection between the two beds, all the drifts which have been run where lignite would be found if there were any between the shafts have failed to find it.

Little woody structure can be seen in pieces of the lignite from the southern bed, but Dr. Jeffrey finds that microscopic examination shows it to be Pityoxylon. "Probably the same as that described by Dr. Knowlton." This is the only coniferous wood thus far described from this place. The specimens of the lignite which were sent to Dr. Jeffrey were numerous and selected with the purpose of sending as great a variety as could be found, but, as will be seen from his article which follows, he was able to make out only three kinds of wood. By far the most numerous specimens were those which Dr. Jeffrey called at first Betuloxylon, but, after fuller examination, concluded that the structure was not sufficiently well preserved to allow of accurate determination and leaves it as some sort of dicotyledonous wood. It is this which is seen in all of the four figures on Plates XLVI and XLVII. With this was found the lignite which Dr. Jeffrey has called *Lauroxylon brandonianum*. Thus in the north shaft we have all the lignite examined, and several hundred sections were made at the Harvard Laboratory, while all that from the other shaft has proved to be gymnospermous.

After what has been said little remains to add by way of special description of the plates. Still a few comments may further explain them.

Figure 1 on Plate XLVI shows one of the commonest of the better preserved lignites. This, as are all of the figures of lignite, is reduced one half. In the actual specimen the grain is more distinct than in the figure.

It is of a dark, chestnut brown color, compact and with clear, woodlike surface. Figure 2 is an unusual specimen in the distinctness of its grain. Probably this is partly due to weathering as the specimen was almost buried in a sod of grass when I found it and had evidently been exposed to sunshine and rain for some time. By this weathering the layers of tissue had been separated more than I ever saw in other specimens, and, of course, thus became more easily seen than at first. Many pieces exposed in the same way would have fallen into shapeless masses, but this had sufficient firmness of texture to withstand the weather.

On Plate XLVII, Figures 1 and 2, we have an end and side view of a large bit of well preserved lignite. The lower figure shows a piece that evidently came from the center of the tree. There is more or less silica and other mineral matter in all the lignite, but in such as that shown in Plate XLVIII there is more than in that just mentioned. In much this is disseminated in so fine particles as to be unnoticeable unless one wishes to cut the lignite, but in the piece shown in Plate XLVIII there are numerous and plainly visible angular bits of white quartz. Attention has already been called to the hollow in this piece from which an *Apeibopsis* has dropped. This sort of lignite readily crumbles if long exposed to water and sun and, as the contained fossils are of firmer texture, they remain uninjured and fall out in very perfect condition. When not crumbled, it usually dries with a scaly or somewhat foliated surface as in the figure.

It is a rather remarkable fact that, while so many fossil fruits have been found in this deposit and in so great variety, few leaves or stems, except the common fragments of tree trunks, have been found. A few, and these not very distinct, fragments of leaves are all that I have ever seen and Dr. Hitchcock and other of the early students of the lignite do not mention anything of the sort. The specimens figured on

PLATE XLVIII.

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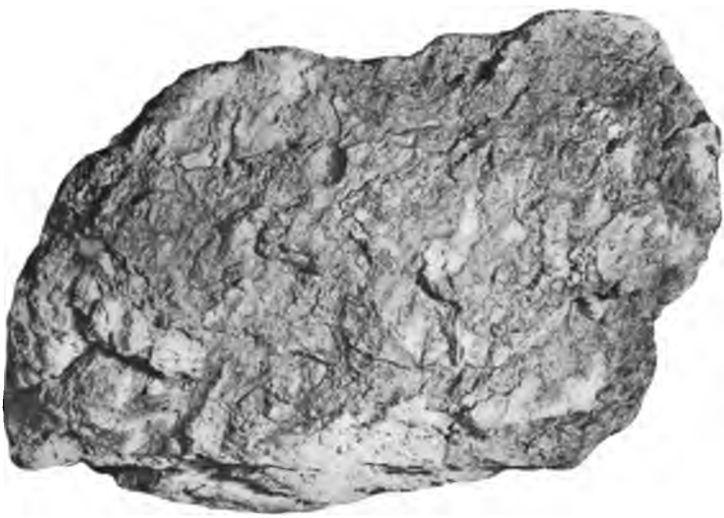

5

Dicotyledonous Leaves in Lignite.

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Plate XLVIII shows the best examples. As the fossil leaves are almost exactly the color of the mass in which they are preserved, it has been difficult to photograph them with much detail. Indeed there is not very much to photograph. Some of the much decomposed bits of the lignite appear to be largely composed of small bits of stems and leaves, but little could be made out of any of these. The stems are mostly covered by a much wrinkled epidermis, as if quite green when mixed up with the surrounding mass, and the same is true of the midribs and larger veins in the specimens figured. The perfect shape of the leaves thus far found in fragments cannot be determined, but it apparently would be much like that of an Ulmus or Betula leaf. The leaves are all netted veined and the little angular bits of white quartz are always associated with the leaf fragments. . It has been my constant hope that some much desired piece of lignite would turn up which should furnish better specimens of the foliage of the trees from which the deposit came, but thus far nothing of the sort has appeared, nor can I find that any of the men who worked in the shafts ever saw any leaves although they had sufficient curiosity to pick up and save fruits which they valued as interesting objects.

In the article by Dr. Knowlton, which was originally published in Torrey Bulletin, November, 1902, and largely quoted in the author's first paper, there is a description of the microscopic structure of some of the lignite and the name *Pityoxylon microporosum brandonianum* given to this form. For two years past Dr. E. C. Jeffrey, of Harvard University, has kindly examined all the specimens of lignite which I have sent and has succeeded remarkably, when the difficulties of the task are considered, in making thin sections so that clear microscopic slides could be prepared. The accompanying plates, though less beautiful than the slides themselves, give a fair idea of the character of the work done. I am sure that not the least interesting part of Dr. Jeffrey's paper will be found in his very lucid account of the methods adopted to secure the results obtained from the intractable material in hand.

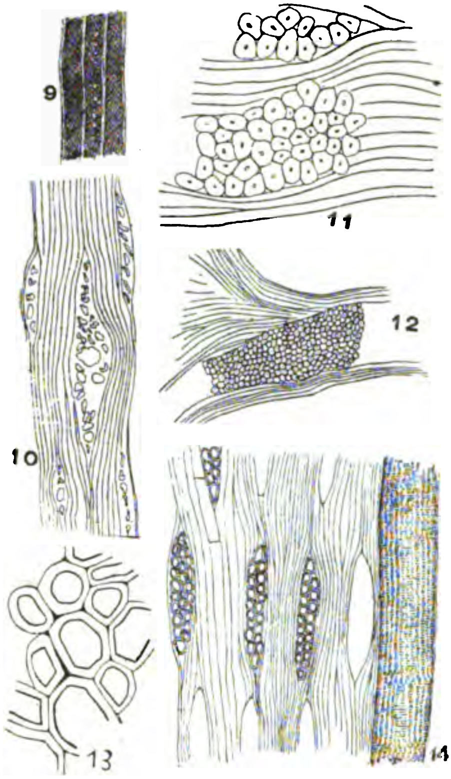


Fig. VI.

9. Pityoxylon microporosum brandonianum, Kn. Radial section.
10. Same tangential.
11. Carpolithes brandonianus. Section near the base x50.
12. Carpolithes brandonianus. Lx. Section near base x50.
13. Aristolochites. Section near the middle x45.
14. Dicotylenous Wood. Tangential Section x75.

As it may be of interest to those who may not otherwise have access to Dr. Knowlton's paper and also give completeness to the subject I repeat here the figure given in the last Report which illustrates the microscopic structure of the lignite which Dr. Knowlton examined.

The Lignites of Brandon.*

BY E. C. JEFFREY and M. A. CHRYSLER.

In the spring of 1904 Professor G. H. Perkins sent to one of us a number of specimens of the fossil woods from the well known Brandon deposits. These were subjected to microscopic examination with the aid of methods described below. The study of this somewhat fragmentary material led to the investigation of a large quantity of the lignites, which was supplied by Professor Perkins from the collections in the Cabinet of the State of Vermont and those of the Museum of the University of Vermont.

In preparing the material for study the following procedure was adopted. The pieces of lignite were sawed into blocks about one cubic centimeter in dimensions, care being taken to have the surfaces of the blocks as nearly as possible parallel with the three planes of section desired, viz.: transverse, radial and tangential. In the less well preserved specimens this was a matter of some uncertainty, but is important on account of the greater resulting facility of cutting sections in accurate planes. The blocks were softened and swelled by soaking for two or three days in alkaline alcoholic solution, made by mixing one part of a 10 per cent. aqueous solution of caustic soda with two volumes of 50 per cent. alcohol. A simple aqueous solution of caustic soda, such as is generally advocated for use in such cases, causes too great and rapid swelling, accompanied by disastrous cracking of the blocks. This evil is corrected by the addition of alcohol, which exercises a restraining influence. The blocks after this treatment were washed for twenty-four hours

*Contributions from the Phanerogamic Laboratories of Harvard University, No. 6.

or more in repeated changes of 50 per cent. alcohol and then transferred to wax-lined bottles containing a mixture of aqueous hydrofluoric acid one part and 30 per cent. alcohol nine parts. This treatment was found necessary to facilitate cutting of sections on account of the large amount of mineral ash contained in the lignites. After a sojourn of two or three days in this fluid, the blocks were well washed in ordinary 30 per cent. alcohol slightly alkalinized and then were run up into absolute alcohol, in which they were kept for at least two days with frequent changes to secure perfect dehydration. In order to secure thin sections of the full size of the blocks it was found necessary to embed the material in celloidin. The method recently described by Plowman (Botanical Gazette, Vol. 37, pps. 456-61, June, 1904.) was found extremely satisfactory for this purpose. The sections were cut 5-7 *micra* thin and in general required no staining on account of the naturally dark brown color of the material. In some cases it was even found advantageous to bleach the sections in chlorine water. After mounting in balsam, the preparations were subjected for several days to a temperature of 50° centigrade, under weight, to insure the perfect flatness necessary for photomicrographic reproduction. With this end in view the mounts were further made on plate glass or polished slides.

The lignites from Brandon have already been investigated by Dr. F. H. Knowlton of the United States Geological Survey (Torrey Bulletin, Nov. 1902, pps. 635-41, pl. 25), but in the interval the active exploitation of the deposits for fuel, resulting from the coal famine of the winter 1902-3, has led to the securing of a considerable amount of new material, which has been supplemented from the collections contained in the cabinet of the State of Vermont and those of the State University of Vermont. The Brandon lignites are considered by Dr. Knowlton to be Miocene.

The first of the fossil woods to be described has apparently come under the notice of no previous investigator of these deposits. It is a superbly preserved Laurinoxylon, which occurs in numerous examples of dark horn-like consistency.

Particular care was required in the treatment with soda and hydrofluoric acid, to bring about the maximum degree of softening, as even under the best conditions the wood proved difficult to section. Photograph 1, Plate XLIX, reproduces the appearance of a transverse section of this species in a region including parts of two annual rings. The autumnal wood is on the lower side of the photograph and presents a contrast to the vernal wood appearing above, only in the smaller size of its vessels. A row of parenchymatous elements often double or even triple terminates the autumnal wood, as is often the case in Dicotyledons. The wood is mainly formed of libriform fibers of small diameter, as is the case in living species of Laurus, but is without the glandular secretory cells, which are the peculiar feature of the nearly allied Persea. The libriform cells frequently have their lumina occupied by dark brown contents. Similar contents are not unusual in the libriform elements of living woods. The vessels are particularly conspicuous in the spring wood on account of their larger size. They are usually solitary but occasionally occur in radially orientated groups of two or even three. A thick jacket of parenchymatous elements surrounds each vessel as in Laurus and allied living species. Photograph 2, Plate XLIX shows the structure of the autumnal wood as seen in transverse section. It is to be noticed in this region of the wood, that the islands of parenchyma, which surround the vessels, fuse together forming meandering tangential stripes.

Photograph 3, Plate XLIX, shows a magnified radial view of the wood. There are obviously two kinds of parenchymatous stripes traversing the wood, longitudinal ones representing the jackets of the vessels and transverse ones, which constitute the medullary rays. The latter are characterized by well marked marginal cells, which, instead of being elongated in the radial direction, as is the case with the central cells of the ray, are either cubical in contour or even longitudinally prolonged. Photograph 4, Plate XLIX, shows another longitudinal view, which in contrast to the last is through the vernal region of the wood. On the left may be seen one of the large vessels. Its sides are dentate at intervals, indicating the position of the original transverse walls, which disappeared when the vessels became mature. Two of the transverse septa have persisted. Frequently the vessels are more or less completely filled with a dark brown homogeneous substance, which in all probability represents mucilage such as is often found in no longer functional vessels in living Dicotyledons. The vessels communicate with each other and with the surrounding parenchymatous cells by numerous pits. These are often very much elongated horizontally, especially where they provide for intercommunication between adjacent vessels. This characteristic pitting of the walls has not escaped the attention of Knowlton in the case of *Laurinoxylon branneri*, occurring from the Eocene to the late Tertiary of Arkansas (Description of Fossil Woods and Lignites from Arkansas, Annual Report Geological Survey of Arkansas, 1889, Vol. 2, pps, 749-767.). In the photograph just described, the marginal cells of the medullary rays can be very well made out.

Photograph 5, Plate XLIX, represents a tangential section, several vessels appear in the field of the photomicrograph and are plainly partially included with the same mucilaginous substance which has already been alluded to above. In this plane of section the medullary rays appear as lenticular masses, from one to three or four cells broad, which are terminated above and below by pointed marginal cells.

Photograph 6, Plate XLIX, shows the structure of the wood in the neighborhood of the vessels as seen in horizontal section highly magnified. Each of the vessels present is obviously surrounded with a layer of elements, which are distinguishable from the libriform fibers which constitute the bulk of the wood, by their larger lumen. These cells when viewed in longitudinal section, as in photographs 3, 4 and 5, are seen to be parenchymatous elements.

The wood described above is named **Laurinoxylon brandonianum** from its origin. The diagnosis is as follows:

Transverse: Vessels occurring singly, but sometimes in twos and threes: 70-140 *micra* in diameter, surrounded by masses of parenchyma, which in the autumn wood tend to join tangentially; rays numerous, narrow; wood mostly formed of narrow libriform elements.

Tangential: Vessels septate, the septa sometimes persistent, lumen often filled with dark brown contents, pits often horizontally elongated; rays with very distinct marginal cells, which are more or less longitudinally prolonged; libriform fibers long with very narrow lumen, often wholly or partially occupied by dark brown contents; parenchyma cells surrounding the vessels two or three times as long as broad, rather thick-walled.

Radial: Vessels with horizontal slit-like pits and often clearly septate, rays with very distinct pointed marginal cells.

In addition to the Laurinoxylon described above, there were present among the lignites from Brandon very numerous examples of another Dicotyledonous wood, in a bad state of preservation. Photograph 7, Plate L, shows a transverse view of one of the less badly preserved specimens of this wood. The rays are obviously large primary ones; with indistinct indications of smaller secondary rays between. The elements of the wood are in general badly preserved, the vessels being most clearly recognizable. The fibers are indistinguishable and it is impossible to decide whether they are fiber-tracheids or of the type ordinarily designated libriform. Photograph 8, Plate L, shows a more highly magnified transverse view of the wood. Here the secondary rays can more clearly be made out and the fact that the vessels are grouped in tangential and not in radial clusters can be distinguished. Photograph 9, Plate L, illustrates the tangential section of the wood, in a specimen which presents the most usual condition of preservation, i. e., that in which the rays alone maintain their structure, the wood proper having more or less completely collapsed. Photograph 10 shows the tangential view more highly magnified. The secondary as well as the primary rays may now be made out. The cells of both kinds of rays are filled with a dark brown substance, which appears to have possessed considerable antiseptic properties as may be inferred from the better preservation of the rays. Photograph 11, Plate L, shows a highly magnified image of the inclined end-walls of the vessels. They are obviously of the scalariform type, which is found in many of the Dicotyledons. The number of bars in the scalariform terminal walls of the vessels varies from 16 to 60. The diameter of the vessels is very variable but averages about 40 *micra*.

It is quite impossible to place this wood with any degree of certainty in its true affinity, on account of its imperfect condition of preservation. It can, however, scarcely be a "Betuloxylon" since the groups of vessels are arranged tangentially and not radially as is the case in the wood of Betula. The description given above will, with the photomicrographs, suffice for its identification in case better preserved specimens of this lignite are subsequently found. It seems probable that the same wood has been referred to by Dr. Knowlton in the article already mentioned.

In one of the specimens of the lignite thus described, an interesting fungus was found. Photograph 12, Plate L, shows the general character of the fungus as seen under low magnification. Photographs 13 and 14, Plate LI, present a somewhat more highly magnified view of the fungus in question. It appears in rounded alveolated masses which are occasionally obviously connected with a mycelium. Photograph 15, Plate LI, shows two of these masses somewhat highly magnified. One of them is clearly in continuity with a mycelial filament. In the same field may be seen what appear to be rounded spores, which have possibly originated from the disintegration of the alveolar masses just described. Professor Farlow has been good enough to examine the fungus, and thinks that it is impossible to say more in regard to its nature, than to indicate that it is a sclerotium stage of some sort. It is accordingly named **Sclerotites brandonianus** from its place of origin. The alvelolar masses are about 80 *micra* in diameter and possess a rather thick outer wall. The internal chambers or spores are sometimes occupied by mycelial filaments. No clamp connections were observed in any of the mycelium.

Only one gymnospermous lignite was found among the remains

PLATE XLIX.

EXPLANATION OF PLATE XLIX.

Figure 1. Transverse Section of the Wood of Laurinoxylon brandonianum, x 45. Page 197.

Figure 2. The same, but showing more of the Autumnal wood, x 45. Page 197.

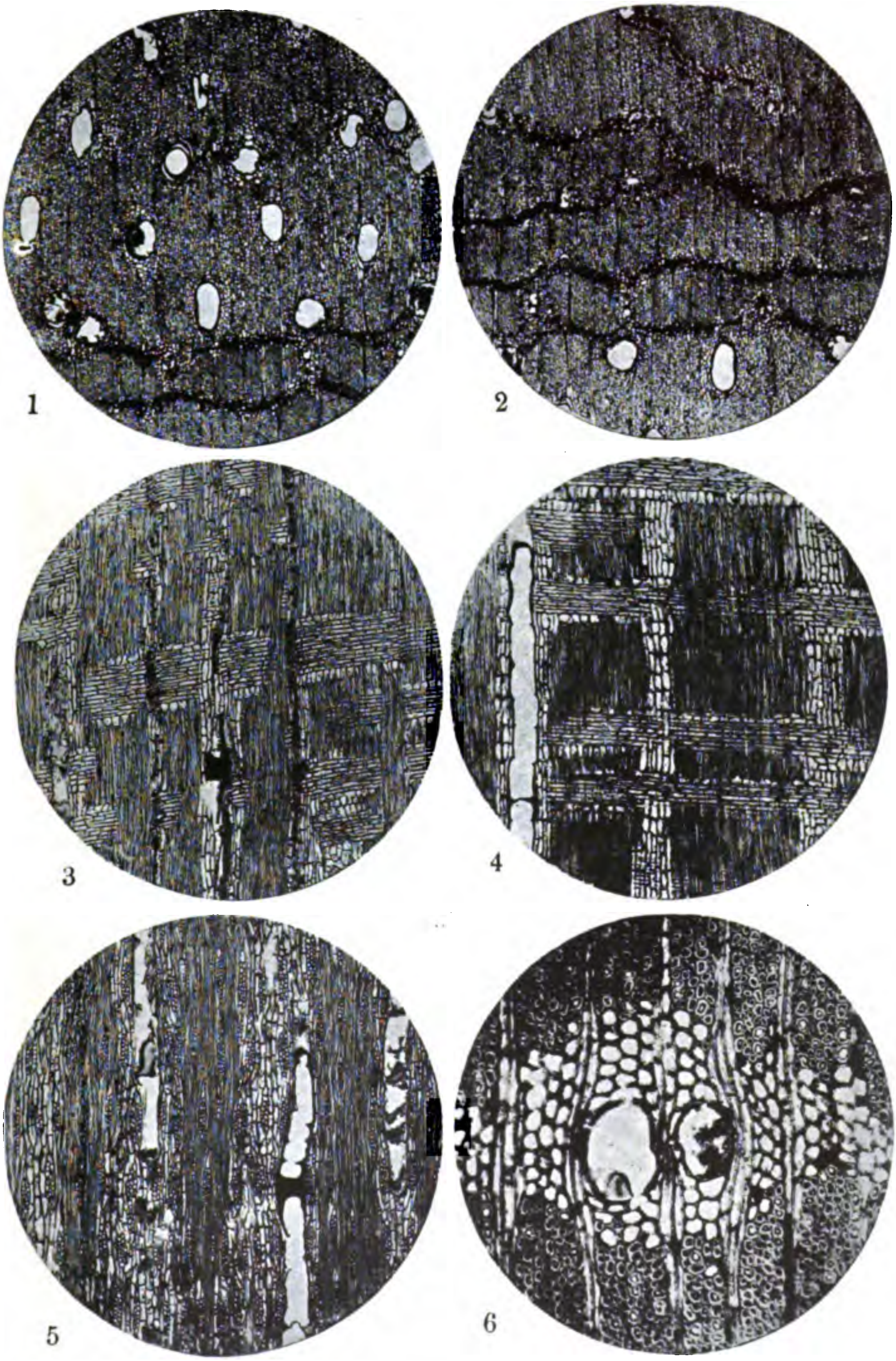
Figure 3. Radial Section of Wood of Laurinoxylon, x 45. Page 197.

Figure 4. Radial Section of Laurinoxylon, x 45. Page 197.

Figure 5. Tangential Section of Wood of Laurinoxylon, x 45. Page 199.

Figure 6. Tangential Section of Laurinoxylon, x 200. Page 199.

PLATE XLIX



SECTIONS OF BRANDON LIGNITE, LAURINOXYLON

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PLATE L.

DESCRIPTION OF PLATE L.

Figure 7. A Dicotyledonous wood, Transverse Section. x 45, Page 199.

Figure 8. The same as the above, but x 180. Page 199.

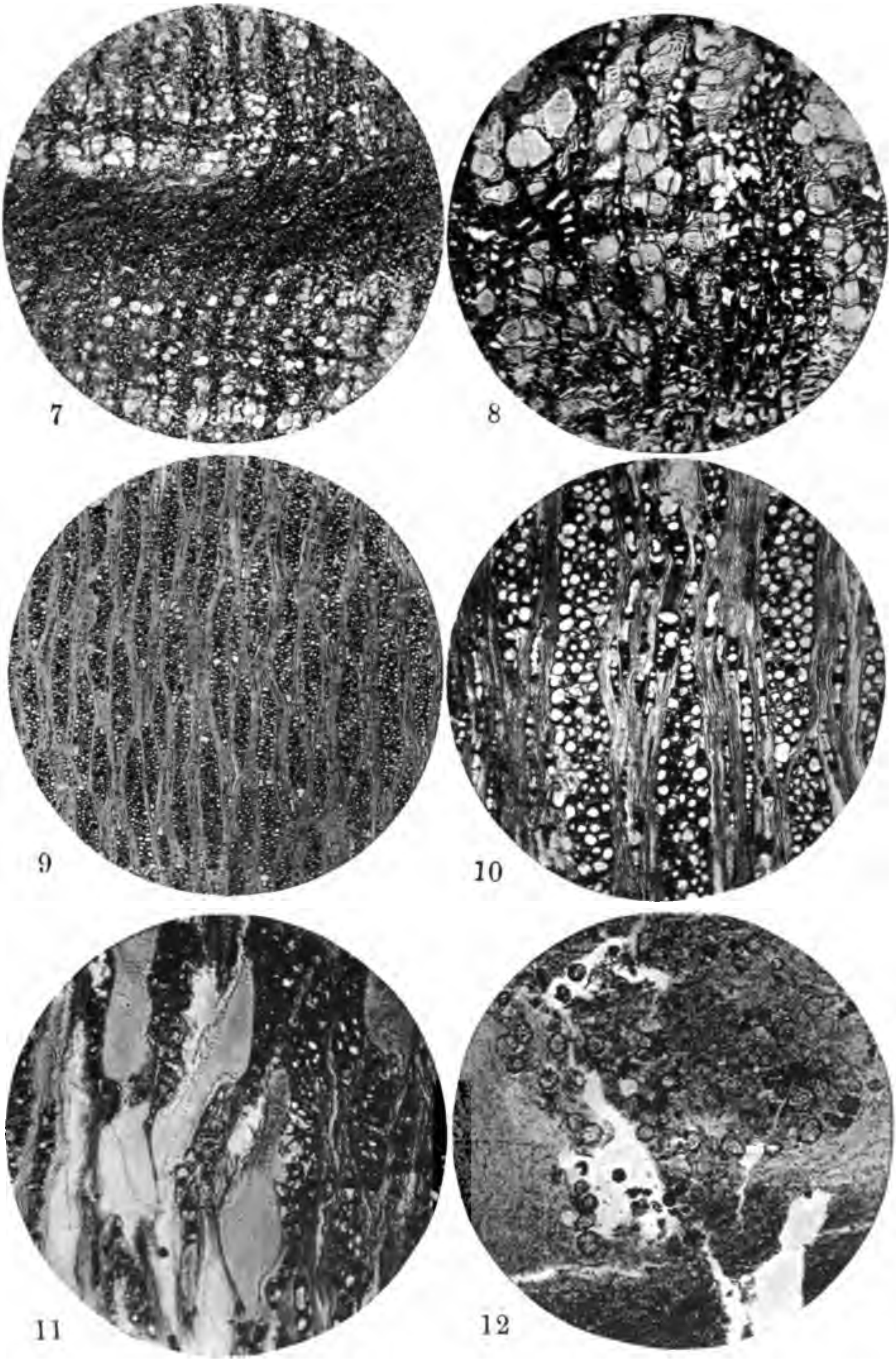
Figure 9. Tangential Section of the same, x 40. Page 199.

Figure 10. The same as the above, but x 180. Page 199.

Figure 11. The same in Tangential Section, x 180. Page 200.

Figure 12. Part of another specimen of the same, x 15. Showing Fungus, Sclerotites brandonianus. Page 200.

PLATE L



SECTIONS OF BRANDON LIGNITE, "BETULOXYLON."

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OF

PLATE LI.

DESCRIPTION OF PLATE LI.

Figure 13. Wood of a Dicotyledonous Tree, Tangential with Sclerotites, Section, x 45. Page 200.

Figure 14. The Same as the Above, x 45. Page 200.

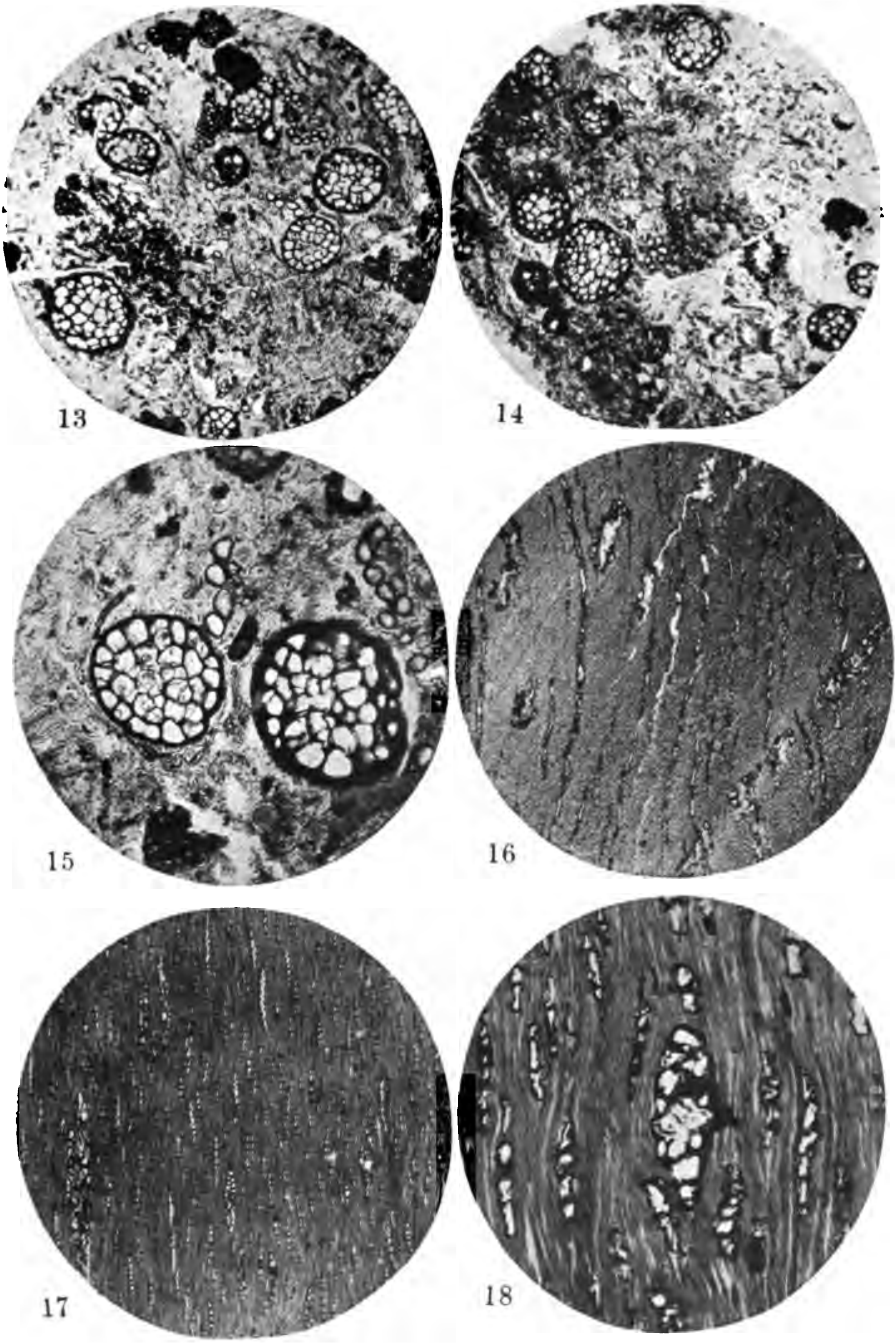
Figure 15. The Same as the Above, but x 180. Page 200.

Figure 16. Wood allied to Pityoxylon, Transverse Section x 25. Page 201.

Figure 17. Tangential Section of the Above, x 25. Page 201.

Figure 18. Part of the Above, but x 180. Page 201.

PLATE LI



SECTIONS OF BRANDON LIGNITE, 13-15 "BETULOXYLON" 15-18 PITYOXYLOID LIGNITE

from Brandon, apparently a species of Pityoxylon, much less well preserved than that mentioned by Dr. Knowlton. (Knowlton, *Op. Cit.*). Photograph 16, Plate LI, shows this lignite in transverse section. It is obviously much decayed but resin canals and medullary rays can still be distinguished, although the tracheary elements have collapsed into an almost homogeneous mass. Photograph 17, Plate LI, shows the features of the tangential plane of section, under a low magnification. The fact that most of the medullary rays are of the linear type, although a few are fusiform, can be made out. Photograph 18, Plate LI, shows one of the fusiform rays and several of the linear rays highly magnified. There can be little doubt that we have here to do with a Pityoxylon, probably the same as that described by Dr. Knowlton in the article already cited, although in both cases the material is too badly preserved for accurate diagnosis..

Fossils of the Lignite.

G. H. PERKINS.

In the paper preceding this the author has mentioned the account of the fossils found in the lignite up to the time of writing. As the Fourth Report stated, a considerable number of new specimens have since been obtained and many of those found long ago have been restudied. The results of this work are presented in the following pages.

In the article on this formation in the Fourth Report the author described 118 species as new and redescribed 20 that had been previously named by Lesquereux and others. In all there are in that Report 172 figures of these fossils. In this Report, besides the description of the lignite itself and its microscopical study just given, 36 new species are described and figured. Two of these were described, but not figured, in the Fourth Report. For convenience of reference, a list of all the described fossils from this deposit is given at the end of this article.

A change in nomenclature has been thought advisable so far as the old genus Carpolithes is concerned. In the previous Report, following Lesquereux and others, several species were referred to this genus. The forms found in the lignite are, however, so well defined and so distinct that it seems best to establish a separate genus for them and accordingly I have proposed the new genus *Glossocarpellites*, so named because of the tongue-like valve opening. In the Bulletin of the Geological Society this term is first used and under it are placed all those species which in the Fourth Report found place under *Carpolithes*. This old genus, never well defined or limited, has become so all inclusive as to be practically without meaning or value. At least this is the opinion of the writer. The above is the only change which has been made.

When we consider the great variety found in the fossils, as shown by the plates in this and the former Report, and the very small variety which Dr. Jeffrey was able to discover in the masses of lignite which he examined, the discrepancy seems incredible. But Dr. Jeffrey assures me that such facts are not unusual in similar cases, that is, it is not uncommon to find in deposits consisting of but a few species of wood a much greater variety of fruits or seeds. And it is easily understood that so readily transported objects as seeds or the lighter fruits would generally be assembled in greater variety than the less movable wood of the trees from which they came whenever any accumulation of the debris of a forest was gathered in a small locality by whatever means. Moreover, the fruits or seeds are much less liable to be destroyed by decomposition than the wood.

Still the large number of species found in the very small area occupied by this deposit is very surprising. It can only be said that the fossils are before us and that it certainly has not been either the intention or desire of the author to create any larger number of species than the character of the specimens warrants. Anyone interested can examine the photographic reproductions of the specimens described and form his own opinion.

Of course it may happen that new masses of the lignite may be uncovered in future digging and intermediate forms thus brought to light which will so connect some of the species now apparently distinct that the number will be reduced, but this does not seem probable.

That forests of some considerable extent existed in Vermont in later Tertiary times is proved by the existence of these deposits, but no slightest trace of them has thus far been discovered aside from this lignite with its fruits. Apparently the great disturbances which occurred during the Pleistocene obliterated all traces of these Miocene forests. If at any time a series of shafts can be sunk upon the lignite deposits, we shall probably thereby not only learn more than we now know as to its area, but undoubtedly, know more about the fossils which it contains. As has been noticed previously, the few shafts which have been dug during the past two or three years in the immediate neighborhood of those from which lignite had been taken did not encounter it at all.

The author hoped, as indicated in the former Report, that extended study of a large number of recent fruits from different parts of the world would throw light upon the character of the Brandon fruits so that, at least in some measure, their botanical affinities could be ascertained. This much desired result has not been reached to any extent. Resemblances in form and external appearance have indeed been found, but anything like identity of the fossil species or genera with modern forms has not been discovered to any extent. In the fossils which have been referred to the modern genus *Nyssa* the affinity of fossil to recent species has been most apparent. Some of the fossil *Nyssas* are quite like some recent species and the same is true in a less degree of the *Cinnamomums* and *Juglans*.

As noticed in a former article, there is greater resemblance, at least superfically, between the Brandon fruits and those of Australia than I have found elsewhere. And in some respects this similarity is very noticeable, but much more complete investigation and comparison than has been possible is necessary before any definite conclusion can be reached. It is interesting in this connection to notice an article on FOSSIL PLANTS FROM THE UPPER TERTIARY AURIFEROUS DRIFTS OF NEW SOUTH WALES by Baron von Muller (Annual Report of the Department of Mines, New South Wales, 1875, Appendix pp. 124-126, Plates 1, 2.) The vegetable remains described and figured in the above article are all fruits and while none of them exactly resemble those we are considering, they are, some of them, not very different from some of ours. It is not stated in this paper that any other fossils aside from fruits, were found in these gravels.

Apparently, the internal structure of the New South Wales fruits can be more completely made out than that of our specimens. Of the three species which Baron von Muller has figured on his two plates, one he regards as belonging to the *Menispermaceae* and the other two to *Coniferae*. The similarity of some of the Brandon fruits to those described by Bowerbank from the London clay of Sheppey and also to those which Heer has described in FLORA HELVETICA was long ago noticed by Lesquereux.

It is believed that the figures of the fruits described in the following pages can convey a more accurate idea of the objects than any descriptions, hence these are made brief. All the figures are, as have been all that have been published by the author, reproductions of photographs. Measurements of average specimens in those cases where several were at hand are given, not because they are of very much value in themselves, but because at least the proportions of the species can best be understood from them. Of course they are to be considered as only approximate for specimens other than that measured.

As two plates published in a Bulletin of the Geological Society of America include some characteristic species taken from the plates in the Fourth Report and also some figures not given elsewhere, I have included them among the plates illustrating this article. For the use of Plates LII and LIII I am indebted to the Society.

Description of Lignite Fossils.

GENUS GLOSSOCARPELLITES, Perkins.

Bulletin G. S. A., Vol. 16, page 510.

As has been stated, those species which in the previous Report were included in the old genus *Carpolithes* are here placed in the new genus *Glossocarpellites*. This may be defined as follows:

Fruit a carpel, oval or ovate in outline, usually large, 25 mm. .75 inch or more in length. In most cases longer than wide. Thickness quite variable. Some species are nearly cylindrical, others flat so that a cross-section is elongate-oval. This is shown on Plate LXXV of the Fourth Report. The fruit is one celled, opening by a single, tongue-shaped valve which is in most cases mucronate at the apex. The surface is variable. It is sometimes smooth as in Figure 16, Plate LIII, or it may be rough as in Figure 17 of the same Plate. The base of the fruit is usually thicker and narrower than the top. The following species are given here. For others see list at the end of this article.

GLOSSOCARPELLITES GRANDIS, Perkins.

Plate LIV, figs. 1. 2, 3.

Carpolithes grandis, 4th Vt. Report, 1904, p. 178.

This is larger than any other species found in the Brandon locality. It is not common, only four or five specimens having been seen. The specimen shown in the figures named is of average size. One considerably larger is among those in the American Museum of Natural History, New York. This was collected many years ago by Dr. Hitchcock and is the specimen figured in the Vermont Report of 1861 and placed by Lesquereux under *Car-*

polithes Brandoniana Var elongata from which it seems to be clearly distinct.

All the specimens found are somewhat imperfect, the valve especially is likely to be missing. For so large a form this is quite thin and flat. It is possible that this may prove to be an unusually large form of *G. brandonianus*, but all the specimens of the two forms thus far discovered are easily separated. The specimen figured is 42 mm. 1.65 in. long, 28 mm. 1 .1 inch wide and 10 mm. .4 inch thick.

Glossocarpellites parvus, Perkins.

Plate LII, fig. 15.

Glossocarpellites parvus, Perkins, Bulletin G. S. A. Vol. 16, p. 510.
Carpolithes parvus, 4th Vermont Rep. p. 179.

Like the preceding, this form was described, but not figured in the last Report. It is much smaller than any other of this genus. It is, however, relatively thicker and narrower.

Genus MONOCARPELLITES, Perkins.

Fourth Report Vt. Geologist, p. 180.

As stated elsewhere, the fruits referred to this genus resemble some of the nuts of modern species of *Juglans*, but I cannot make them identical. This form is usually oval or ovate, surface in most cases regularly ribbed lengthwise or, instead of ribs, there may be furrows. There is but a single cell opening by a more or less triangular valve. Most of the species are comparatively thin as found, but, in some measure at least, this may be due to flattening. The greater number are of medium size.

Monocarpellites appear to have been more abundant in the forests which made the lignite than other forms, or else they have been less liable to decomposition. With the number of specimens at hand, it is extremely difficult to discover how much allowance to make for individual variation, but the following species appear to the author to be well defined.

MONOCARPELLITES AMYGDALOIDUS, nov. sp.

Plate LIV. fig. 4.

Fruit elongated-oval, blunt pointed at each end, surface not ribbed except at the upper end, where there are few sharp ridges or elevations which extend about a third of the distance below the end. The cell walls are very thick and the remains of the cavity shows in cross section as a strongly curved line. Length, 26 mm., 1 inch, breadth, 15 mm., .65 inch, thickness, 9mm., .35 inch.

MONOCARPELLITES MULTICOSTATUS, nov. sp.

Plate LIV. figs. 5, 6, 7.

Form broadly ovate, flat on one side, moderately convex on the other. Surface covered with numerous, but not very distinct, costæ, there being about ten on each side. These ribs are very regular and equidistant. They are not as distinct in the figure as they should be. The surface is not smooth, but, as the figure shows, roughened by fine and rather irregular papillæ. As figure 7 shows, the cell walls are thick and the cavity much curved. This fruit is unlike any other that I have seen and appears to be well preserved. As figure 6 of the edge shows, it is a moderately thick form. The upper end is mucronate, lower thicker and rounded. Length, 24 mm., .9 inch, width, 21 mm., .85 inch, thickness, 10 mm., .4 inch.

MONOCARPELLITES PRUNIFORMIS. nov. sp.

Plate LIV, fig. 8.

This species resembles *M. amygdaloidus*, but is much heavier and larger. Its form, that of a plum stone, suggests the specific name. The surface is not ribbed, but is somewhat wrinkled and roughened. The ends are blunt edges somewhat angular, walls thick and consequently the cavity must have been small. Length 30mm., 1.2 inch, width, 17mm., .68 inch, thickness. 12 mm .5 inch.

GENUS BICARPELLITES Perkins,

4th Report Vermont Geologist.

On examination by cross section a considerable number of the Brandon fossils proved to be two celled. The form of these was very variable. Indeed a short acquaintance with these fruits shows that the external appearance is no guide to their internal structure, and it is often impossible to decide whether a given specimen is one, two or three celled before sectioning. Evidently many of the specimens were not fully ripened when they were fossilized and hence, if the valves would ever have opened, they had not done so, and even when in mature specimens the valves are plainly open, in immature ones of the same sort the line of dehiscence is scarcely visible. Most of the larger species did finally have wide open valves, but often they are entirely closed in the fossil. Some of those that are one celled are thicker, and even more triangular, than some of those that are two or three celled. I have found no large fruit that was more than three celled and only a few of the smaller species, though some of these latter are many celled.

I am not unaware that my classification, by which all one celled fruits are separated from two celled and three celled from each of these, is open to criticism, since in recent plants the number of cells in the fruit may not always be the same in different species of the same genus. Therefore it is not true that difference in the number of cells necessarily indicates generic difference though usually it does. Under the circumstances, however, it seems best to place the fossils in groups according to the number of cells found by making a section across them. Of course these are not the only characters by which they can be arranged.

The following species are placed in the genus *Bicarpellites*, mainly because they are two celled, while those forms most nearly allied to them in appearance have a different number.

BICARPELLITES ABBREVIATUS, nov. sp.

Plate LVI, fig. 1.

This is one of the smaller forms. It is nearly orbicular in outline, rather thin, upper end acuminate, lower rounded and, as is usually the case, thicker. The surface is costate there being six sharp ribs. The valves are triangular, distinct, open about a third of the length. The lower end in the specimen figured shows a distinct cicatrix. Length, 17mm., .67 inch, width, 15mm., .57 inch, thickness, 8mm., .3 inch.

BICARPELLITES ATTENUATUS, nov. sp.

Plate LIV, fig. 9.

This species is of a form quite unusual among these fossils. In cross section it is nearly quadrangular. The sides are straight and the ends blunt pointed. On each of the broader sides there are two or three irregular ribs. The form and thickness, nearly equal to the width, serve to define this species. Length, 30mm., 1.2 inch, width, 22mm., .46 inch, thickness, 19mm., .35 inch.

BICARPELLITES BICARINATUS, nov. sp.

Plate LIV, fig. 10.

This fruit is of medium or small size, oval in outline, rather thick, ribs few, but well defined, two of these forming prominent carinae, especially on one side, though on the reverse side there are two ribs much more prominent than the others. Indeed, these two larger ribs are the only ones that are continued from end to end, the others fading out as they approach the lower end. Both ends are rather blunt, valves thin, opening half the length, acuminate. Section quadrangular. Length, 23mm., .9 inch, width, 15mm., .6 inch, thickness, 8mm., ,35 inch.

BICARPELLITES CARINATUS, nov. sp.

Plate LIV, fig. 11.

Fruit of medium size, oval in outline, thick, but with thin, pointed valves which open less than half the length. Ribs few, one in the middle of one side forms a sort of carina, whence the name. Upper and lower ends more nearly equal than is usual.

Section irregular. Length 23mm., .9 inch, width 15mm., .6 inch, thickness 8mm., .33 inch.

This is somewhat similar to the foregoing, but it is unlike it in shape and proportions..

BICARPELLITES CRASSUS, nov. sp.

Plate LV, figs. 2 and 3.

Fruit large, heavy, quadrangular in section broadly oval in outline. Valves triangular, opening about a third of the whole length. Ends obtuse and similar. The surface bears few, but very wide costae. Length 27mm., .1.05 inch, width 20mm., .75 inch, thickness 10mm., 4 inch.

BICARPELLITES CRATERIFORMIS, nov. sp.

Plate LV, fig. 1.

This very singular form may be due to distortion, but so far as its appearance indicates, it is not much deformed, if at all. It is wider than long, which is very unusual in these fossils. In fact I have seen no other specimen which showed this feature as prominently. As the figure shows, the surface is costate, the ribs being distinct, somewhat irregular and unequal. At the lower end is a distinct cicatrix much like that seen on a nutmeg. Length, 19 mm., .175 inch, width, 24 mm., .95 inch, thickness, 10 mm., .35 inch.

BICARPELLITES INEQUALIS, nov. sp.

Plate LV, fig. 4.

This is a medium sized species, thick, surface smooth, but grooved, outline irregular or rather unequal, quadrangular in section, cell walls only moderately thick. Length, 22 mm., .85 inch, width, 15 mm., .61 inch, thickness, 10 mm., .4 inch.

BICARPELLITES LANCEOLATUS, nov. sp.

Plate LV, fig. 5.

The name indicates the general form of this species. In the figure it is somewhat enlarged. It is thin, with thin, pointed valves. About four prominent ribs on each side. Lower end blunt, upper sharp pointed. Length, 27 mm., 1.05 inch, width, 16 mm., .65 inch, thickness, 6 mm., .6 inch.

BICARPELLITES LATUS, nov. sp.

Plate LV, figs. 6, 7.

Fruit broadly spatulate, regular, upper portion very thin so that the edges are sharp. There are six pretty well defined ribs on each side. The lower end is wedge-shaped and thicker than the upper. Length, 26 mm., 1.03 inch, width, 22 mm,, .8 inch, thickness, 8 mm., .7 inch. It is possible that this form and that shown in figure 1 should be placed in the same species, the latter being distorted, but on the whole I am inclined to regard them as distinct.

BICARPELLITES MAJOR, nov. sp.

Plate LV, figs. 8, 11, 12.

This species in many respects reminds one of some of the forms found in *Juglans* of the present, but it also shows important differences. As the figures show, it is one of the largest of our fruits. The surface is irregular, not distinctly ribbed, ends pointed, cross section, as in figure 8 quadrangular with crescentic cavities. Thick, as shown in figure 11. The walls are moderately thick, as shown in figure 8. Probably the fruit has shrivelled somewhat. The specimen figured is 39 mm., 1.5 inch long, 21 mm., .82 inch, wide, 12 mm., .47 inch thick.

BICARPELLITES MEDIUS, nov. sp.

Plate LV, figs. 9, 10.

This species in form closely resembles a *Glossocarpellites*, but its two cells are, as figure 10 shows, very plainly shown. It is of medium size of an oval outline, valves opening widely and half the length. Surface without ribs, but somewhat rough. Sides and edges flattened. Length, 23 mm., .9 inch, width, 14 mm., .56 inch, thickness, 7 mm., .28 inch.

BICARPELLITES BREVIS, nov. sp.

Plate LV, fig. 13.

This is one of the smallest *bicarpellites* that has been found. As the figure shows, it is somewhat distorted, though not greatly. There are five large and not prominent ribs. Probably the original outline was oval. Relatively it is rather thick. The length is only 15 mm., .6 inch, width, 11 mm., .45 inch, thickness, 5 mm., .2 inch.

BICARPELLITES OVATUS, nov. sp.

Plate LV, fig. 14.

This is an elegant little species of very regular ovate outline. The figure shows it somewhat enlarged. The surface bears a few very large not prominent ribs. One side is much more convex than the other, the more convex being shown. The valves are thin, pointed, and open more than half the length. It has much the appearance of some of the *Monocarpellites*, but is plainly two celled. Length, 20 mm., .8 inch, width, 15 mm., .8 inch, thickness, 9 mm., .35 inch.

BICARPELLITES PAPILLOSUS, nov. sp.

Plate LV, fig. 15.

This is a large, fine species, distinctly marked by numerous not very distinct longitudinal furrows. Between these narrow furrows the surface forms low, rounded ribs which when slightly magnified are seen to be rows of papillæ. I have not been able to get a photograph that shows this well and it can be only very indistinctly seen in the figure. There are some 18 or 20 of these furrows in all and, of course, the same number of low ribs or ridges. The papillæ are formed by the crossing of fine lines which divide the ribs into many little squares and each of these rises in a little rounded tubercle or papilla. In cross section this form is much like figure 8, but is less angular. The ends are rounded and very similar. At one end are two thin valves opening only a small portion of the length. It seems very possible that this fruit, as also many of the others, had originally a husk or shelly covering of some sort, but if so all traces of it have disappeared. The length of this species is, in the specimen figured, 31 mm., 1.23 inch, width, 19 mm., .73 inch, thickness, 14 mm., .55 inch.

BICARPELLITES, PARVUS, nov. sp.

Plate LV, fig. 16.

Aside from *B. minimus* and *brevis*, this is the smallest of the genus. The surface is smooth, but there is a not very distinct rib running through the middle as seen in the figure 9, each side of this is an indistinct rib. Each end is somewhat pointed. The valves are broadly triangular and open only a short distance. Length, 17 mm., .65 inch, width, 12 mm., .5 inch, thickness, 8 mm., .3 inch.

BICARPELLITES QUADRANGULATUS, nov. sp.

Plate LVI, fig. 2.

Fruit apparently much shrunken, cross section strongly quadrangular, but it was probably more nearly cylindrical when fresh. That is, this species seems to have been more succulent than most and consequently it has suffered more change of form. It is plainly two celled and was attached to a stem at the lower end. There are no ribs or other elevations on the surface. Length, 21 mm., .85 inch, width, 13 mm., .5 inch, thickness, 10 mm., .4 inch.

BICARPELLITES QUADRATUS, nov. sp.

Plate LVI, fig. 3.

Fruit of more than medium size, thick, heavy, sides nearly flat so that a cross section is nearly a regular quadrangle. The outline is also more quadrate than is usual. The surface is indistinctly ribbed and is rather rough. The thin, pointed valves open but a short distance, not more than a fourth of the length. The two cells are very distinct and separated by a thin septum. Length, 24 mm., .9 inch, width, 18 mm., .7 inch, thickness, 9 mm., .35 inch.

BICARPELLITES SOLIDUS, nov. sp.

Plate LVI, fig. 4.

Fruit of medium size, rather thick, surface with numerous pretty regular ribs which converge at the lower end. The thick valves open about half the length. This species closely resemble *Monocarpellites ovalis* and would be placed with that were it not plainly two celled. Still, this is smaller and thicker. Length, 22 mm., .8 inch, width, 17 mm., .65 inch, thickness, 9 mm., .35 inch. The above apply to the specimen figured, which is shown somewhat enlarged, other specimens are larger.

BICARPELLITES SULCATUS, nov. sp.

Plate LVI, figs. 5, 6.

Fruit lance-oval in outline. Four well defined ribs on each surface. These ribs are rounded and rather wide. Except that it is two celled, this form would be placed with the *Monocarpellites* which, exteriorly, it much resembles. As figure 6 shows, the valves open wide and for about half the length. In this, as in many other of these fossils, one valve is much more widely open than that on the opposite side. As in so many of these specimens, the lower end is blunt and the ribs converge at a cicatrix, while the upper end is thinner and sharp pointed. As I have elsewhere noticed, it is very commonly the case with these fruits that the upper end is much thinner and sharper than the lower. This is a medium sized form, the length being 25 mm., 1 inch, width, 17 mm,, .7 inch, thickness, .1 mm., .45 inch.

GENUS TRICARPELLITES, Bowerbank.

TRICARPELLITES CURTUS, nov. sp.

Plate LVI, figs. 7, 8.

This is one of the smaller fruits and resembles a large beech nut. As the figures show, it is about equally three sided, and the width is but little less than the length. The valves open only a short distance, surface for the most part without ribs, but sometimes there are indistinct elevations at the lower end, but they soon fade out. The length is 18 mm., .73 inch; width, 13 mm., .5 inch.

TRICARPELLITES TRIANGULARIS, nov. sp.

Plate LVI, figs. 9, 10.

This is a very distinct and unusually regular triangular form. Each of the three sides, which are nearly equal, is broadly ovate, strongly ribbed by somewhat irregular and sharp ridges, two of which on each side are especially conspicuous, the others being more or less incomplete. This species is larger than most, though by no means one of the largest. I have seen only one specimen which is well preserved and perfect in form. It is in the Dartmouth collection and was kindly loaned by Professor Hitchcock. The three cells are plainly seen. It is 25 mm., 1 inch long, and each side is about 18 mm., .7 inch wide.

TRICARPELLITES ALATUS, nov. sp.

Plate LVI, figs. 11, 12.

This is a very distinct fruit. It is strongly three lobed, but the lobes are so prominent and thin that they may with much propriety be considered as wings, as the end view, Figure 12, shows. This was to all appearance when fresh a thin walled, large celled fruit. The surface bears a few, but strong ribs. I have seen several specimens of this species, but it is not a common form. It is of medium size, the length being 25 mm., 1 inch; width, 14 mm., .6 inch.

TRICARPELLITES BRANDONIANUS, nov. sp.

Plate LVI, figs. 13, 14.

Fruit strongly trilobate, lobes rounded, the form being well shown in Figure 14. At the ends, especially the upper, as may be seen in Figure 13, there are quite distinct ribs, which, however, become more or less indistinct in the middle. The cell walls are very thick and the cavity of each must have been small. The upper end is sharply mucronate. Length, 25 mm., 1 inch; width, 15 mm., 1 inch.

GENUS HICOROIDES, Perkins.

Fourth Rep. Vt. Geologist, p. 183.

HICOROIDES LEVIS, nov. sp.

Plate LVI, fig. 15.

Although in the entire absence of ribs and in some other respects, this form differs from the species of this genus figured in the Fourth Report, yet on the whole it appears well to place it in this group. The surface is not unlike a plum pit in appearance. The form is broadly ovate, one side is much more convex than the other. It is two celled, moderately thin and differs in appearance markedly from any other of these fossils. Length, 18 mm., .7 inch, width, 16 mm., .65 inch; thickness, 8 mm., .33 inch.

GENUS NYSSA, Gron.

In the Fourth Report seventeen species of the genus Nyssa were described and figured. As was there pointed out, some of the fossils approach closely recent species of the same genus.

While looking over a collection of the Brandon fossils in the Museum of the Canadian Geological Survey in Ottawa several species of Nyssa appeared. Two are sufficiently unlike those formerly described to deserve separation into species of their own. These fruits were collected many years ago, undoubtedly when the lignite was first studied and probably by Sir William Logan. They were kindly loaned for study by Dr. Ami.

NYSSA ACUTICOSTATA, nov. sp.

Plate LVI, figs. 16, 17.

Fruit oval, somewhat compressed, surface furrowed by eleven regular, equi-distant, sharp ribs. The sharp, thin edges of the ribs easily distinguish this species, since in all the rest the ribs are more or less rounded. As in most of the specimens of this genus, there is a deep and very distinct cicatrix. This may be seen in the end view, Figure 17, though it is not there as distinct as in the actual specimen. Length, 1 mm., .7 inch; width, 11 mm., .42 inch. Type in Museum of the Canadian Geological Survey at Ottawa.

NYSSA OVALIS, nov. sp.

Plate LVII, fig. 1.

This is a short and rather wide form, broadly oval in outline. It is considerably compressed. On each side there are three rounded costae and several smaller and less distinct between them. The entire surface is irregularly wrinkled the wrinkles being usually fine. Both ends are blunt and the stem scar is less distinct than usual. Length, 15 mm., .6 inch; width, 11 mm., .42 inch. Type in Museum of the Canadian Geological Survey.

NYSSA LESCURII, Hitchcock.

Plate LVII, fig. 2 also Plate LII, fig. 9.

This form I have with some hesitation referred to the above species which it resembles, but there are also points of difference. The ribs are less uniform and for the most part alternate, a large one with one much smaller, while in the type the ribs are very nearly equal. Still, the resemblance is so great that I place it in the same at least provisionally. The specimen figured is in the Museum of the Canadian Geologoical Survey.

NYSSA COMPLANATA, Lesq.

Plate LVII, figs. 3, 5.

This is one of the most common in the lignite. It was described and figured in the Vermont Report of 1861 and in the Fourth of this series. On account of its small size it does not appear in many collections of these fossils though it is easily found at the locality when there is any lignite there to be investigated. A considerable number of additional specimens have been found since the last Report was issued and a few remarks may well supplement what has already been stated. The species is, at least within limits, very variable in size and form, still it is not difficult to identify it in its various proportions.

The usual length of this species is 6 or 8 millimeters and the width about half as much. Some of the specimens are plump and cylindrical, others are much flattened. When fresh they were all undoubtedly regularly cylindrical. The figures referred to above show the specimens enlarged about twice.

NYSSA CURTA, Perkins.

Fourth Vt. Rep. p. 199.

Plate LVII, figs. 4, 6.

Figures of this and the above species are introduced here mainly because the figures in the previous report are greatly enlarged and do not give as good an idea of the actual appearance of the fossils as these which are only twice full size. As stated in the description, this may prove to be merely a shortened form of N. *complanata*, but further study of a larger number of specimens confirms the belief that it is distinct.

GENUS LESCURIA, nov. sp.

The specimens which I have referred to this new genus have hitherto been regarded as very elongated specimens of N. complanata, but recent examination of a much larger number of specimens and especially the discovery that the internal structure is very different from that of Nyssa has caused the proposal of the above genus.

This genus may be characterized as follows: Fruit small, slender, more or less regularly cylindrical, about 10 mm. long, and 3 in diameter. Two celled, the cells opening at the top by valves. Walls thin.

LESCURIA ATTENUATA, nov. sp.

Plate LVII, Figs. 7, 10.

Aside from the generic characters just given it may be said of this species that it is somewhat variable in form, the surface strongly wrinkled, ends pointed or tapering. Apparently this was somewhat soft when fresh and has shrivelled more than most of the fossils.

In some specimens there are tolerably regular longitudinal ridges which may be due to shrivelling or may have existed on the fruit originally, but other specimens show only irregular wrinkles. The figures show the specimens enlarged about one half. In figure 10 the length is 9 mm., .75 inch, width, 4 mm., .18 inch.

GENUS SAPINDOIDES, Perkins.

Fourth Rep. Vt. p. 296.

SAPINDOIDES URCEOLATUS, nov. sp.

Plate LVII, figs. 11, 12.

This is a very interesting and distinct form. I have seen but two specimens.

It appears to be a little distorted and was probably when fresh more nearly globular than in the fossil. As figure 12 well shows, the stem scar is very distinct. The surface was originally smooth, but it is now finely wrinkled in both specimens, though much more in one.

It is 13 mm., .52 inch in transverse diameter and a little less in vertical diameter.

SAPINDOIDES AMERICANUS, Perkins.

Plate LVII, figs. 14, 15.

In the above figures a natural section of this fossil is shown thus giving something of the internal structure. There appears to have been a thick rind or pericarp inside of which was a pulpy mass indistinctly separated by an oblique partition.

GENUS PRUNOIDES, Perkins.

Fourth Rep. Vt. p. 208.

PRUNOIDES INEQUALIS, nov. sp.

Plate LVII, fig. 13.

The figure shows the one sided form of this species. The surface is smooth but indented by numerous irregular depressions. In appearance this form is much like many acacia seeds and it may be allied to that genus. It is 15 mm., .6 inch long, 10 mm., .4 inch wide and 6 mm., .25 inch thick.

GENUS APEIBOPSIS, Heer.

APEIBOPSIS GAUDINII, Lesq.

Plate LVII, figs. 16, 17.

These figures are introduced in order to show natural sections or divisions. They show that the fruit naturally separated into sections of varying number in different species, as indicated usually by the valves. The specimens figured were loaned by Professor Hitchcock.

APEIBOPSIS HEERII, Lesq.

Plate LVIII, fig. 7.

Mr. C. M. Winslow of Brandon has kindly loaned me several fine specimens of the lignite fossils and one of these is shown in the above figure. It is unusually large for the species, but there is no other to which it can be assigned. The figure shows well the position of the fruit in the mass of lignite and, aside from this, it is better than any figure of this species hitherto published. It may prove to be a larger and distinct species, but it seems probable that it is a large form of the species named.

In the Hitchcock collection of Brandon fossils belonging to the American Museum of Natural History, New York, there are two forms which are quite different from any others. These are shown in Figures 1 and 4 of Plate LVIII. I have seen no other entire specimens except those in the American Museum but fragments such as are shown in Figures 2, 3, 5 of Plate LVIII are not very uncommon. The specimen shown in Figure 1 of the plate named is that from which Hitchcock's Figures 157 and 158 of the 1861 Vermont Geological Report and Lesquereux's description in the second volume of the same Report were taken. It was named by Lesquereux *Carpolithes venosus* as he, though doubtfully, considered it sufficiently near Sternberg's species to receive this name. As I can see no reason whatever for placing this fossil in the genus *Carpolithes* it is here placed in the new genus *Staphidoides*.

GENUS STAPHIDOIDES, Gen. nov.

Fruit covered by a rather thin pericarp which wrinkles greatly in drying so that the appearance is quite suggestive of a raisin. General form, oval or ovate. When fresh these fruits were most probably like grapes in form, hence the name (from Staphis, a raisin, dried grape.) All the specimens thus far seen are of medium size and are much lighter in color, at least on the outside, than any of the other fossils. The surface, aside from the wrinkles, is smooth.

STAPHIDOIDES VENOSUS, (Lesq.) Perkins.

Plate LVIII, fig. 1.

This species is described by Lesquereux as "Deeply sulcate and veined" but it is best described as strongly wrinkled, for the surface evidently owes its irregularity wholly to the shrinking of the outer rind or skin when drying. The figure does not show this as clearly as could be wished, but close observation will bring it out fairly well. The specimen is seen to be still imbedded in the lignite. Apparently, the outer skin was filled with some sort of pulp though only fine black carbonaceous matter remains. Lesquereux speaking of this fossil in the Vermont Report says "This is apparently a Carya, it is about the same thickness as *Carya olivæformis*." I fail to discover either in the internal structure or external appearance anything in this species which suggests *Carya*, although I have examined all the specimens of this genus contained in the Pringle Herbarium. There is a second specimen of this fossil in the American Museum. The specimen figured is 13 mm., .5 inch long and 11 mm., .44 inch wide. It is shown somewhat more than natural size in the figure.

STAPHIDOIDES OVALIS, nov. sp.

Plate LVIII, figs. 2, 3, 4, 5.

This is in some respects unlike the preceding, but I am inclined to place it in the same genus. It is larger and the wrinkling much more pronounced, but in most respects it is like *S. venosus*. The only complete specimen found is that shown in Figure 4, of Plate LVIII and, like the foregoing, is among the specimens collected fifty years or more ago by Dr. Hitchcock, and is now in the American Museum. By the kindness of the Museum authorities I have had the opportunity of studying these interesting specimens. As seen well in the figures, the wrinkles are larger and the form and appearance differ from that of the preceding species. It may properly be noticed that this is much more distinctly seen in the actual specimens than in the photographs. It appears to be more abundant, though not many specimens and those in fragments, have been found. In most cases whatever has been found is still imbedded more or less in the lignite as that shown in Figure 4 and also that in 5, which is in the Dartmouth College collection, show. The other specimen figured was in the lignite when found but has been worked out. Figure 3 is the same as 2 enlarged about twice. In all the specimens the rind or skin is yellowish brown and is somewhat flexible and elastic though the outside of 4 is darker than that of the others. The inside is completely changed to a fine dark brown lignite. The dimensions of the specimen shown in Figure 4, where it is somewhat enlarged are: Length, 23 mm., .85 inch; width, 15 mm., .57 inch.

GENUS, LEGUMINOSITES.

LEGUMINOSITES PISIFORMIS, Heer.

Geology of Vermont, 1861, page 231, fig. 152.

This is a very rare fruit or seed as it is easily destroyed because it consists only in a thin brittle shell. It is small, 5 mm., in diameter and instead of the dull unpolished surface which is found in nearly all the Brandon fossils, this has a black and shining exterior. There are four specimens of this species in the American Museum. Although I think it very doubtful indeed if this species is identical with that described from Œningen by Heer, yet I leave it where Lesquereux placed it as I have not seen Heer's specimens. Lesquereux appears to have been in doubt for he says "Though the identity of our species with *Leguminosites pisiformis* common at Œningen is not certain it is, however, remarkable that most of these seeds that have about the same form as ours belong to the upper Tertiary."

There is in our collection another very small fruit which is not figured and which I will not attempt to name. It is only about 2½ mm. in diameter, of globular form, deeply six lobed. In the center there is a cylindrical core from which fibers radiate in all directions to the outside. The external surface is rough under a lens. At the calyx end there is a deep pit and a stem at the opposite. Apparently there was some sort of a pericarp.

Figure 6, of Plate LVIII, shows a thick rind, or envelop, which apparently surrounded a pit. It is the only specimen of the sort that I have seen. It may be a very large celled *Glossocarpellites* in which the walls have not been pressed together so that the cell cavity is closed as in most specimens. The specimen from which the photograph was taken was loaned by Hon. C. M. Winslow.

For convenience of reference the following list of all species described from the Brandon Lignite is appended.

List of Species Described from the Brandon Lignite.

Apeibopsis gaudinii, Lesq. Am. Jour. Science, XXXII, page 358, Geol. Vt. 1861, p. 715.

Apeibopsis heeri, Lesq. Am. Jour. Science, XXXXII, p. 358, Geol. Vt. 1861, p. 716.

Apeibopsis parva, Perkins, Fourth Rep. Geol. Vt. 1904, p. 202, Pl. LXXX, figs. 148, 152.

Aristolochia obscura, Lesq. Am. Jour. Science, XXXII, p. 359, Geol. Vt. 1861, p. 715.

Aristolochites acutus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 202.

Aristolochites apicalis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 203.

Aristolochites brandonianus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 205.

Aristolochites conoideus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 203.

Aristolochites crassicostatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 205.

Aristolochites cuneatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 206.

Aristolochites curvatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 205.

Aristolochites dubius, Perkins, Fourth Rep. Geol. Vt. 1904, p. 204.

Aristolochites elegans, Perkins, Fourth Rep. Geol. Vt. 1904, p. 203.

Aristolochites excavatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 205.

Aristolochites globosus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 206.

Aristolochites irregularis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 204.

Aristolochites latisulcatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 204.

Aristolochites majus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 206.

Aristolochites ovoides, Perkins, Fourth Rep. Geol. Vt. 1904, p. 203.

Aristolochites rugosus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 203.

Aristolochites sulcatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 204.

Bicarpellites abbreviatus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 209.

Bicarpellites attenuatus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 210.

Bicarpellites bicarinatus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 210.

Bicarpellites brevis, Perkins, Fifth Rep. Geol. Vt. 1906, p. 213.

Bicarpellites carinatus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 210.

Bicarpellites crassus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 211.

Bicarpellites crateriformis, Perkins, Fifth Rep. Geol. Vt. 1906, p. 211.

Bicarpellites grayana, (Lesq.) Perkins, Fourth Rep. Geol. Vt. 1904, p. 190.

Bicarpellites inequalis, Perkins, Fifth Rep. Geol. Vt. 1906, p. 211.

Bicarpellites knowltoni, Perkins, Fourth Rep. Geol. Vt. 1904, p. 191.

Bicarpellites lanceolatus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 211.

Bicarpellites latus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 212.
Bicarpellites major, Perkins, Fifth Rep. Geol. Vt. 1906, p. 212.
Bicarpellites medius, Perkins, Fifth Rep. Geol. Vt. 1906, p. 212.
Bicarpellites minimus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 192.
Bicarpellites obesus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 191.
Bicarpellites ovatus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 213.
Bicarpellites papillosus, Perkins. Fifth Rep. Geol. Vt. 1906, p. 213.
Bicarpellites parvus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 214.
Bicarpellites quadrangularis, Perkins, Fifth Rep. Geol. Vt. 1906, p. 214.
Bicarpellites quadratus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 214.
Bicarpellites rotundus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 191.
Bicarpellites rugosus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 191.
Bicarpellites solidus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 215.
Bicarpellites sulcatus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 215.
Bicarpellites vermontanus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 192.
Brandonia globulus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 192.
Carpites inequalis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 193.
Carpites ovalis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 194.
Carpites trigonus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 194.
Glossocarpellites (Carpolithes) brandonianus, (Lesq.) Am. Jour. Sci. XXXII, p. 356, 1861.
Glossocarpellites (Carpolithes) elongatus, Perkins, Fourth Rep. Geol. Vt. 1904.
Glossocarpellites (Carpolithes) emarginatus, Perkins, Fourth Rep. Geol. Vt. 1904.
Glossocarpellites (Carpolithes) grandis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 178.
Glossocarpellites (Carpolithes) hitchcocki, Perkins, Fourth Rep. Geol. Vt. 1904, p. 179.
Glossocarpellites (Carpolithes) mucronatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 179.
Glossocarpellites (Carpolithes) obtusus, (Lesq.) Perkins, Fourth Rep. Geol. Vt. 1904, p. 177.
Glossocarpellites (Carpolithes) ovatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 178.
Glossocarpellites (Carpolithes) parvus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 179.
Glossocarpellites (Carpolithes) simplex, Perkins, Fourth Rep. Geol. Vt. 1904, p. 178.
Glossocarpellites (Carpolithes) solidus, Perkins. Fourth Rep. Geol. Vt. 1904, p. 179.
Glossocarpellites (Carpolithes) vermontanus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 179.

Cinnamomum corrugatum, Perkins, Fourth Rep. Geol. Vt. 1904, p. 200.
Cinnamomum lignitum, Perkins, Fourth Rep. Geol. Vt. 1904, p. 200.
Cinnamomum novæ-angliæ, Lesq. Am. Jour. Sci. XXXII, p. 360, 18
Cinnamomum ovoides, Perkins, Fourth Rep. Geol. Vt. 1904, p. 199.
Cucumites lesquereuxii, Knowlton, Bull. Torrey Bot. Club, XXIX, p. 641, 1902.
Drupa rhabdosperma, Lesq. Am. Jour. Sci. XXXXII, p. 360, 1861.
Hicoria biacuminata, Perkins, Fourth Rep. Geol. Vt. 1904, p. 193.
Hicoroides angulata, Perkins, Fourth Rep. Geol. Vt. 1904, p. 183.
Hicoroides ellipsoidea, Perkins, Fourth Rep. Geol. Vt. 1904, p. 184.
Hicoroides globulus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 184.
Hicoroides levis, Perkins, Fifth Rep. Geol. Vt. 1906, p. 217.
Hicoroides parva, Perkins, Fourth Rep. Geol. Vt. 1904, p. 184.
Hicoroides triangularis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 183.
Illicium lignitum, Lesq. Am. Jour. Sci. XXXII, p. 360, 1861.
Juglans brandonianus. Perkins, Fourth Rep. Geol. Vt. 1904, p. 182.
Lescuria attenuata, Perkins, Fifth Rep. Geol. Vt. 1906, p. 220.
Monocarpellites amygdaloidus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 181.
Monocarpellites elegans, Perkins, Fourth Rep. Geol. Vt. 1904, p. 181.
Monocarpellites gibbosus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 181.
Monocarpellites hitchcockii, Perkins, Fourth Rep. Geol. Vt. 1904, p. 182.
Monocarpellites irregularis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 181.
Monocarpellites medius, Perkins, Fourth Rep. Geol. Vt. 1904, p. 182.
Monocarpellites multicostatus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 208.
Monocarpellites orbicularis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 181.
Monocarpellites ovalis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 182.
Monocarpellites pruniformis, Perkins, Fifth Rep. Geol. Vt. 1906, p. 208.
Monocarpellites pyramidalis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 180.
Monocarpellites sulcatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 180.
Monocarpellites vermontanus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 182.
Monocarpellites whitfieldii, Perkins, Fourth Rep. Geol. Vt. 1904, p. 180.
Nyssa acuticostata, Perkins, Fifth Rep. Geol. Vt. 1906, p. 218.
Nyssa ascoidea, Perkins, Fourth Rep. Geol. Vt. 1904, p. 196.
Nyssa clarkii, Perkins, Fourth Rep. Geol. Vt. 1904, p. 199.
Nyssa complanata, Lesq. Am. Jour. Sci. XXXII, p. 361, 1861.
Nyssa crassicostata, Perkins, Fourth Rep. Geol. Vt. 1904, p. 196.
Nyssa curta, Perkins, Fourth Rep. Geol. Vt. 1904, p. 199.

Nyssa cylindrica, Perkins, Fourth Rep. Geol. Vt. 1904, p. 195.
Nyssa elongata, Perkins, Fourth Rep. Geol. Vt. 1904, p. 197.
Nyssa equicostata, Perkins, Fourth Rep. Geol. Vt. 1904, p. 198.
Nyssa excavata, Perkins, Fourth Rep. Geol. Vt. 1904, p. 199.
Nyssa jonesii, Perkins, Fourth Rep. Geol. Vt. 1904, p. 197.
Nyssa lamellosa, Perkins, Fourth Rep. Geol. Vt. 1904, p. 195.
Nyssa lescurii, C. H. Hitchcock, Portland Soc. Nat. Hist. I, p. 95, 1862.
Nyssa levigata, Lesq. Am. Jour. Sci. XXXII, p. 361, 1861.
Nyssa microcarpa, Lesq. Am. Jour. Sci. XXXII, p. 361, 1861.
Nyssa multicostata, Perkins, Fourth Rep. Geol. Vt. 1904, p. 197.
Nyssa ovalis, Perkins, Fifth Rep. Geol. Vt. 1906, p. 218.
Nyssa ovata, Perkins, Fourth Rep. Geol. Vt. 1904, p. 196.
Nyssa solea, Perkins, Fourth Rep. Geol. Vt. 1904, p. 194.
Pinus conoides, Perkins, Fourth Rep. Geol. Vt. 1904, p. 209.
Pinus cuneatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 209.
Prunoides bursæformis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 208.
Prunoides inequalis, Perkins. Fifth Rep. Geol. Vt. 1906, p. 221.
Prunoides seelyi, Perkins, Fourth Rep. Geol. Vt. 1904, p. 209.
Rubioides lignita, Perkins, Fourth Rep. Geol. Vt. 1904, p. 193.
Sapindoides americanus, Lesq. Am. Jour. Sci. XXXII, p. 357, 1861.
Sapindoides cylindricus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 208.
Sapindoides medius, Perkins, Fourth Rep. Geol. Vt. 1904, p. 207.
Sapindoides minimus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 208.
Sapindoides parva, Perkins, Fourth Rep. Geol. Vt. 1904, p. 207.
Sapindoides urceolatus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 220.
Sapindoides varius, Perkins, Fourth Rep. Geol. Vt. 1904, p. 206.
Sapindoides vermontanus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 207.
Staphidoides ovalis, Perkins, Fifth Rep. Geol. Vt. 1906, p. 223.
Staphidoides venosus, (Lesq.) Am. Jour. Sci. XXXII, p. 223, 1861.
Tricarpellites acuminatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 190.
Tricarpellites amygdaloidus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 188.
Tricarpellites carinatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 186.
Tricarpellites castanoides, Perkins, Fourth Rep. Geol. Vt. 1904, p. 187.
Tricarpellites contractus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 189.
Tricarpellites curtus, Perkins, Fifth Rep. Geol. Vt. 1906, p. 216.
Tricarpellites dalei, Perkins, Fourth Rep. Geol. Vt. 1904, p. 186.
Tricarpellites elongatus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 186.
Tricarpellites fagoides, Perkins, Fourth Rep. Geol. Vt. 1904, p. 188.
Tricarpellites fissilis, Lesq. Am. Jour. Sci. XXXII, p. 356, 1861.
Tricarpellites hemiovalis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 190.
Tricarpellites lignitus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 186.
Tricarpellites major, Perkins, Fourth Rep. Geol. Vt. 1904, p. 189.
Tricarpellites obesus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 188.

Tricarpellites ovalis, Perkins, Fourth Rep. Geol. Vt. 1904, p. 187.
Tricarpellites pringlei, Perkins, Fourth Rep. Geol. Vt. 1904, p. 189.
Tricarpellites rostratus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 187.
Tricarpellites rugosus, Perkins, Fourth Rep. Geol. Vt. 1904, p. 187.
Tricarpellites seelyi, Perkins, Fourth Rep. Geol. Vt. 1904, p. 189.
Tricarpellites triangularis, Perkins, Fifth Rep. Geol. Vt. 1906, p. 216.

It has been noticed on a preceding page that all of the species named *Carpolithes* in the Fourth Report have been placed in the new genus *Glossocarpellites*. This genus was first mentioned in Bulletin 21 of Geological Society of America, page 510. The old genus *Carpolithes* is so very undefined and the Brandon forms are so clearly distinct from other fossils that it seemed to the writer that they should be grouped in a genus of their own rather than be placed in the exceedingly heterogeneous group that is included under the old genus. Those fruits are included in the genus *Glossocarpellites* which are one celled, of considerable size, usually 25 mm. or more long, walls rather thick, deshiscence by means of a single tongue-shaped valve (hence the name), which is more or less pointed at the apex. The surface in most species is roughened, though in some it is smooth. In most cases the lower end is narrowed and rounded. *G. brandonianus* may be taken as the type.

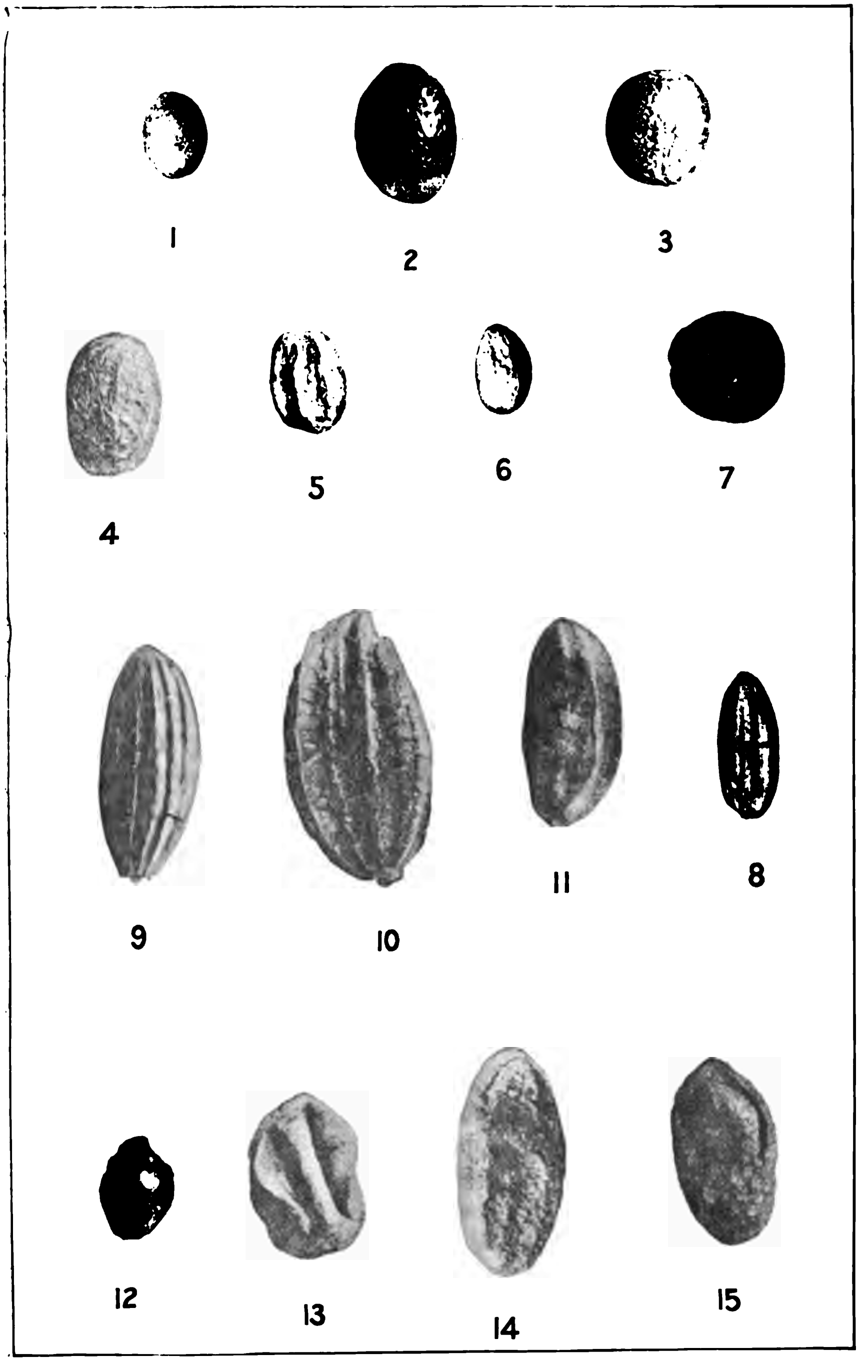
In the above list no references are given to plates or figures, but it may be noticed that nearly all are figured in the works referred to, and the location of the illustration is given at the place to which attention is directed.

PLATE LII.

EXPLANATION OF PLATE LII.

Figure 1. Sapindoides medius, Perkins.
Figure 2. Sapindoides varius, Perkins.
Figure 3. Sapindoides americanus, Perkins.
Figure 4. Aristolochites majus, Perkins.
Figure 5. Aristolochites sulcatus, Perkins.
Figure 6. Aristolochites elegans, Perkins.
Figure 7. Apeibopsis gaudinii, Lesquereux.
Figure 8. Nyssa jonesii, Perkins.
Pigure 9. Nyssa lescurii, C. H. Hitchcock.
Figure 10. Nyssa lamellosa, Perkins.
Figure 11. Nyssa crassicostata, Perkins.
Figure 12. Prunoides seelyi, Perkins.
Figure 13. Bicarpellites knowltonii, Perkins.
Figure 14. Bicarpellites rugosus, Perkins.
Figure 15. Glossocarpellites parvus, Perkins.

PLATE LII.



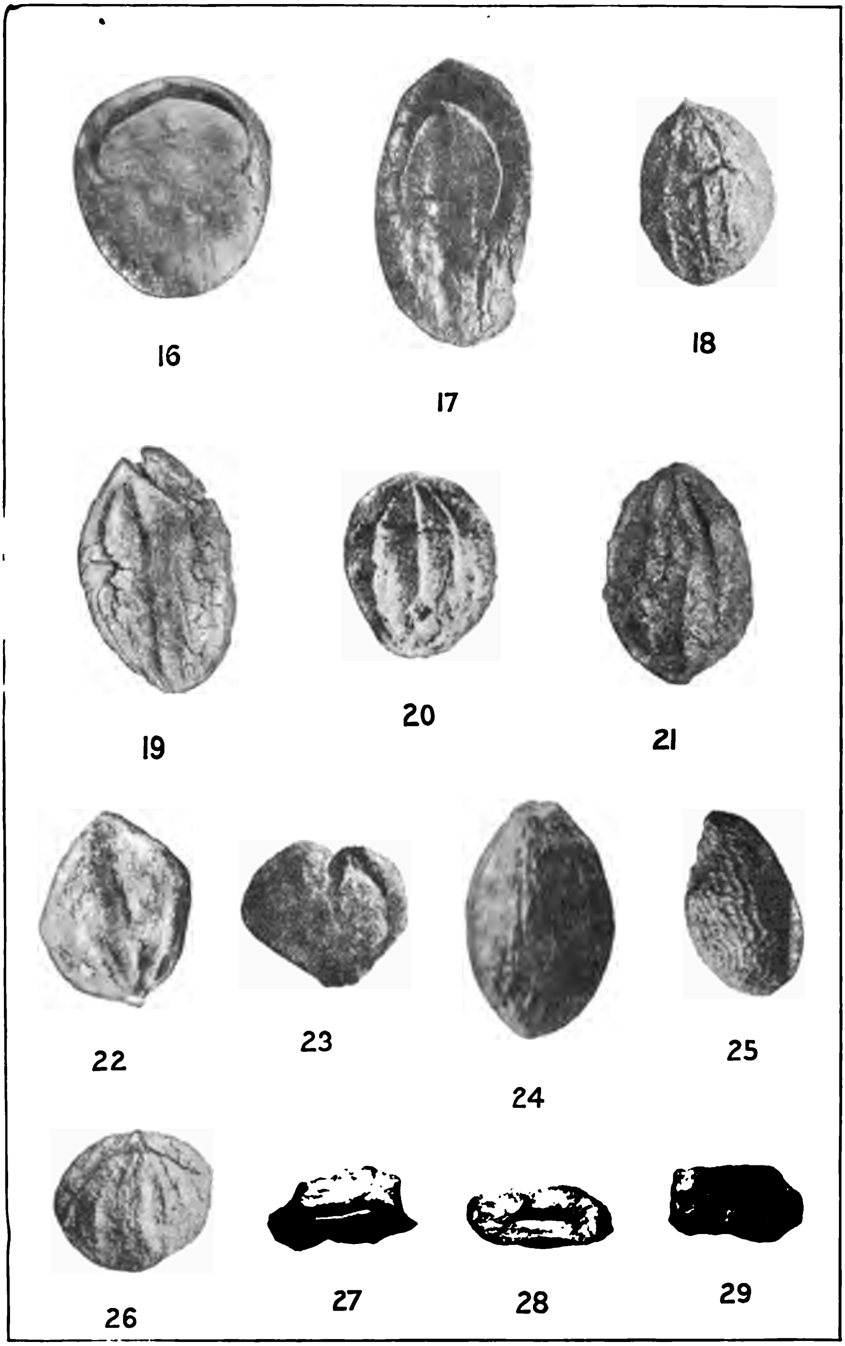
Fossils of the Brandon Lignite.

PLATE LIII.

EXPLANATION OF PLATE LIII.

Figure 16. Glossocarpellites obtusus, (Lesq.) Perkins.
Figure 17. Glossocarpellites elongatus, (Lesq.) Perkins.
Figure 18. Monocarpellites gibbosus, Perkins.
Figure 19. Tricarpellites fissilis, (Lesq.) Perkins.
Figure 20. Monocarpellites sulcatus, Perkins.
Figure 21. Juglans brandonianus, Perkins.
Figure 22. Hicoria biacuminata, Perkins.
Figure 23. Brandonia globulus, Perkins.
Figure 24. Cinnamomum lignitum, Perkins. (Enlarged three times.)
Figure 25. Drupa rhabdosperma. Lesquereux. (Enlarged five times.)
Figure 26. Hicoroides ellipsoideus, Perkins.
Figure 27. Hicoroides angulata, Perkins.
Figure 28. Cross section of Monocarpellites.
Figure 29. Cross section of Bicarpellites.

PLATE LIII.



Fossils of the Brandon Lignite.

PLATE LIV.

EXPLANATION OF PLATE LIV.

Figure 1. Glossocarpellites grandis, Perkins, Front. Page 206.

Figure 2. Glossocarpellites grandis, Side. Page 206.

Figure 3. Glossocarpellites grandis, Back. Page 206.

Figure 4. Monocarpellites amygdaloideus, Perkins. Page 208.

Figure 5. Monocarpellites multicostatus, Perkins, Front. Page 208.

Figure 6. Monocarpellites multicostatus, Edge. Page 208.

Figure 7. Monocarpellites multicostatus, Section. Page 208.

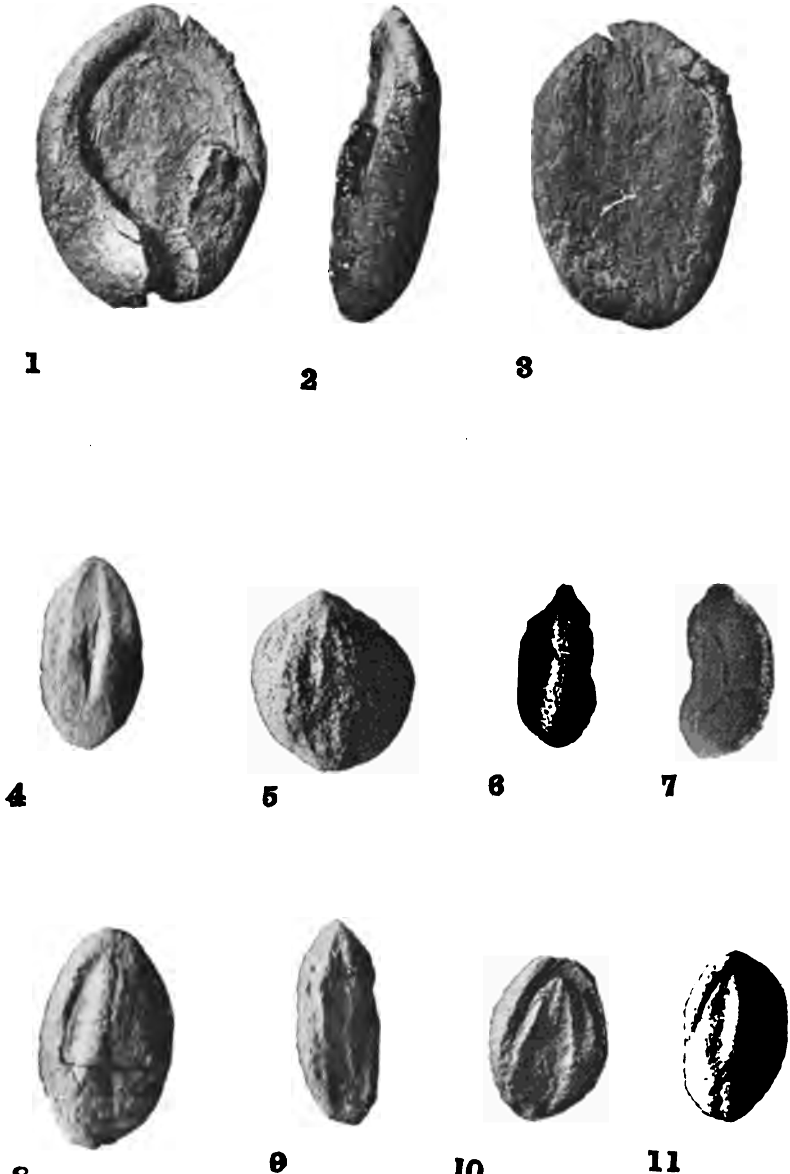
Figure 8. Monocarpellites pruniformis, Perkins. Page 208.

Figure 9. Bicarpellites attenuatus, Perkins. Page 210.

Figure 10. Bicarpellites bicarinatus, Perkins. Page 210.

Figure 11. Bicarpellites carinatus, Perkins. Page 210.

PLATE LIV.



Fossils of the Brandon Lignite.

PLATE LV.

EXPLANATION OF PLATE LV.

Figure 1. Bicarpellites crateriformis, Perkins. Page 211.

Figure 2. Bicarpellites crassus, Perkins. Page 211.

Figure 3. Bicarpellites crassus, Side. Page 211.

Figure 4. Bicarpellites inequalis, Perkins. Page 211.

Figure 5. Bicarpellites lanceolatus, Perkins. (Enlarged.) Page 211.

Figure 6. Bicarpellites latus, Perkins. Page 212.

Figure 7. Bicarpellites latus, Side. Page 212.

Figure 8. Bicarpellites major, Cross section.

Figure 9. Bicarpellites medius, Perkins. Page 212.

Figure 10. Bicarpellitee medius, Side. Page 212.

Figure 11. Bicarpellites major, Perkins, Side. Page 212.

Figure 12. Bicarpellites major, Front. Page 212.

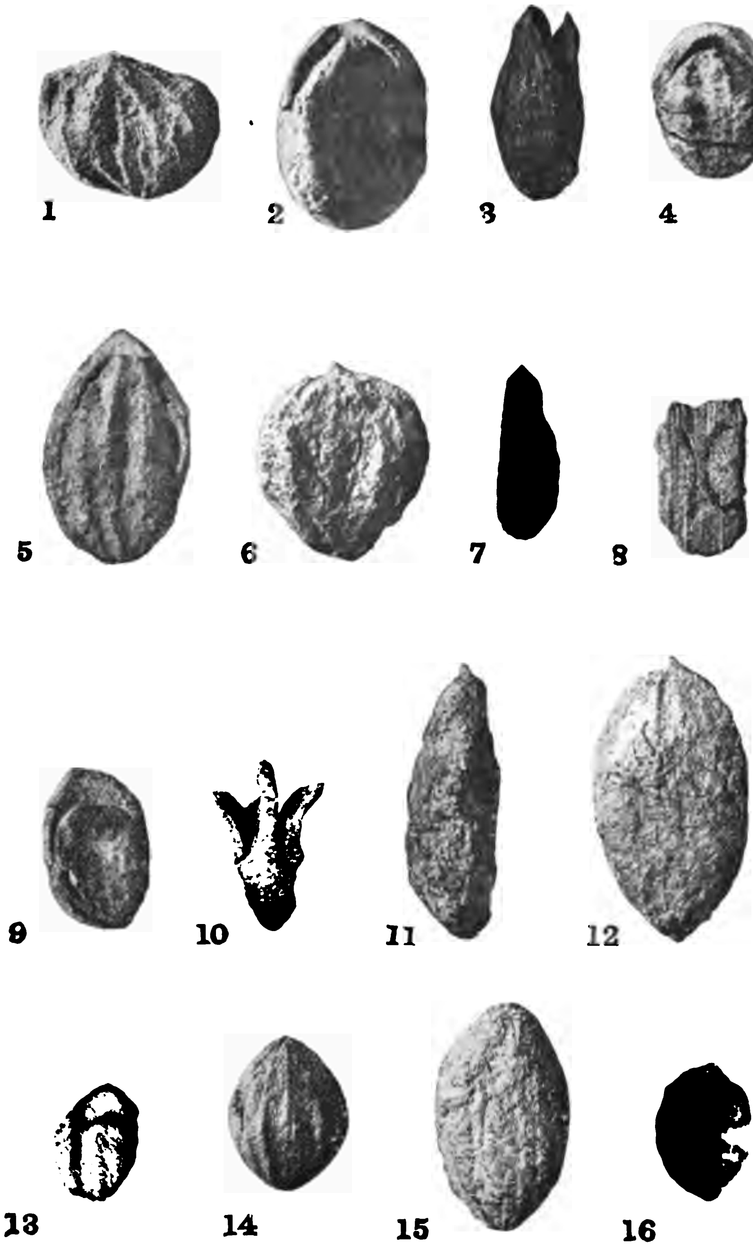
Figure 13. Bicarpellites brevis, Perkins. Page 213.

Figure 14. Bicarpellites ovatus, Perkins. Page 213.

Figure 15. Bicarpellites papillosus, Perkins. Page 213.

Figure 16. Bicarpellites parvus, Perkins. Page 214.

PLATE LV.



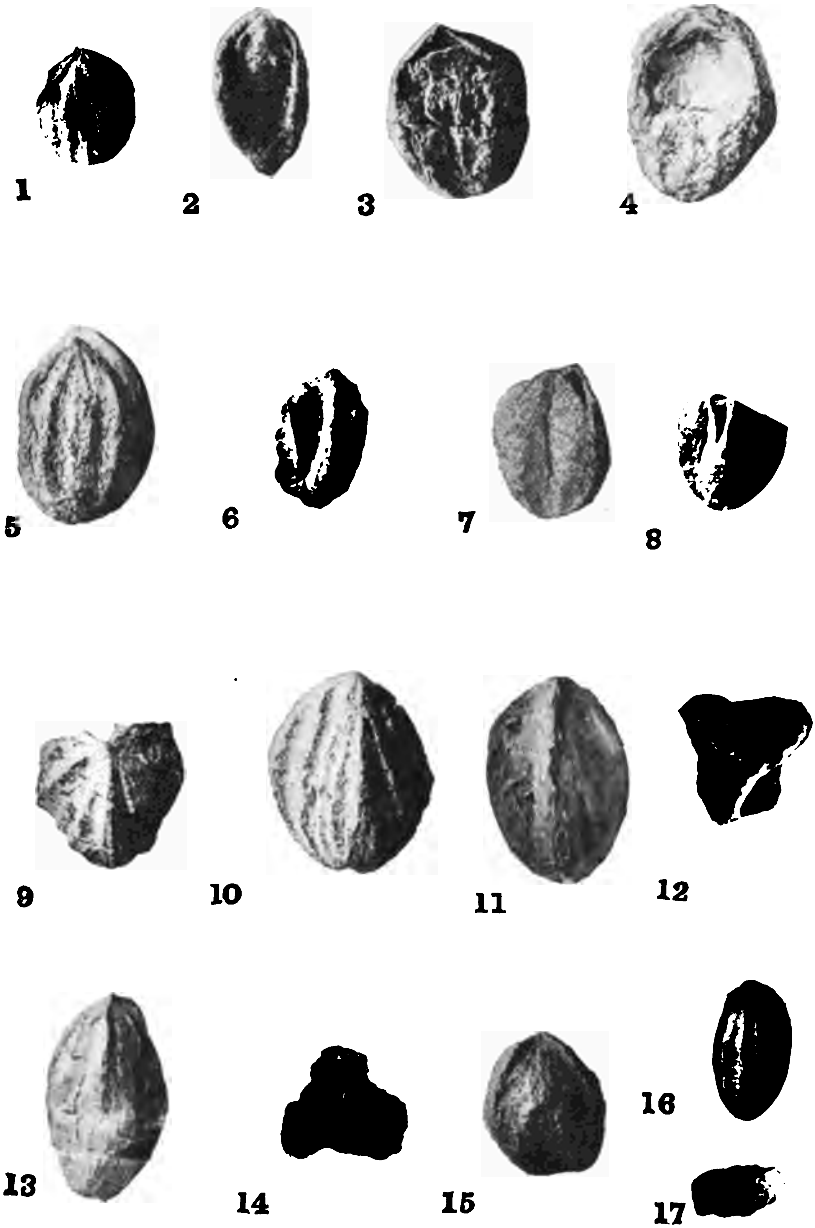
Fossils of the Brandon Lignite.

PLATE LVI.

EXPLANATION OF PLATE LVI.

Figure 1. Bicarpellites abbreviatus, Perkins. Page 209.
Figure 2. Bicarpellites quadrangularis, Perkins. Page 214.
Figure 3. Bicarpellites quadratus, Perkins. Page 214.
Figure 4. Bicarpelites solidus, Perkins. Page 215.
Figure 5. Bicarpellites sulcatus, Perkins. Page 215.
Figure 6. Bicarpellites sulcatus, Side. Page 215.
Flgure 7. Tricarpellites curtus, Perkins. Page 216.
Figure 8. Tricarpellites curtus, End. Page 216.
Figure 9. Tricarpellites triangularis, Perkins, End. Page 216.
Figure 10. Tricarpellites triangularis, Side. Page 216.
Figure 11. Tricarpellites alatus, Perkins, Side. Page 216.
Figure 12. Tricarpellites alatus, End. Page 216.
Figure 13. Tricarpellites brandonianus, Perkins, Front. Page 217.
Figure 14. Tricarpellites brandonianus, section. Aage 217.
Figure 15. Hicoroides levis, Perkins. Page 217.
Figure 16. Nyssa acuticostata, Perkins. Page 218.
Figure 17. Nyssa acuticostata, End. Page 218,

PLATE LVI.



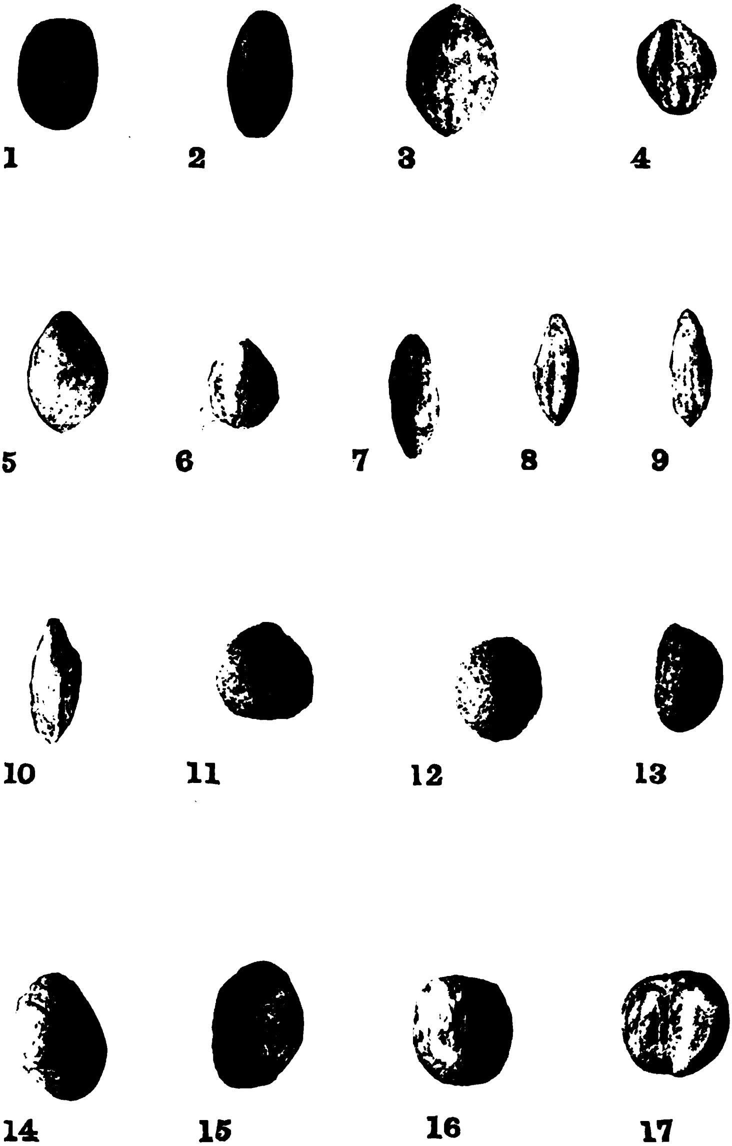
Fossils of the Brandon Lignite.

PLATE LVII.

EXPLANATION OF PLATE LVII.

Figure 1. Nyssa ovalis, Perkins. Page 218.
Figure 2. Nyssa lescurii, C. H. Hitchcock. Page 218.
Figure 3. Nyssa complanata, Lesq. Page 219.
Figure 4. Nyssa curta, Perkins. Page 219.
Figure 5. Nyssa complanata, Lesq. Page 219.
Figure 6. Nyssa curta, Perkins. Page 219.
Figures 7, 8, 9, 10. Lescuria attenuata, Perkins. Page 220.
Figure 11. Sapindoides urceolatus, Perkins, Side. Page 220.
Figure 12. Sapindoides urceolatus, Upper end. Page 220.
Figure 13. Prunoides inequalis, Perkins. Page 221.
Figure 14. Sapindoides varius, Perkins.
Figure 15. Sapindoides varius, Natural section.
Figures 16, 17. Apeibopsis gaudinii, Lesq., Natural section.

PLATE LVII.



Fossils of the Brandon Lignite.

PLATE LVIII.

EXPLANATION OF PLATE LVIII.

Figure 1. Staphidoides venosus, (Lesq.)Perkins. Page 223.

Figure 2. Staphidoides ovalis, Perkins. (Natural size.) Page 223.

Figure 3. Staphidoides ovalis. (Enlarged twice.) Page 223.

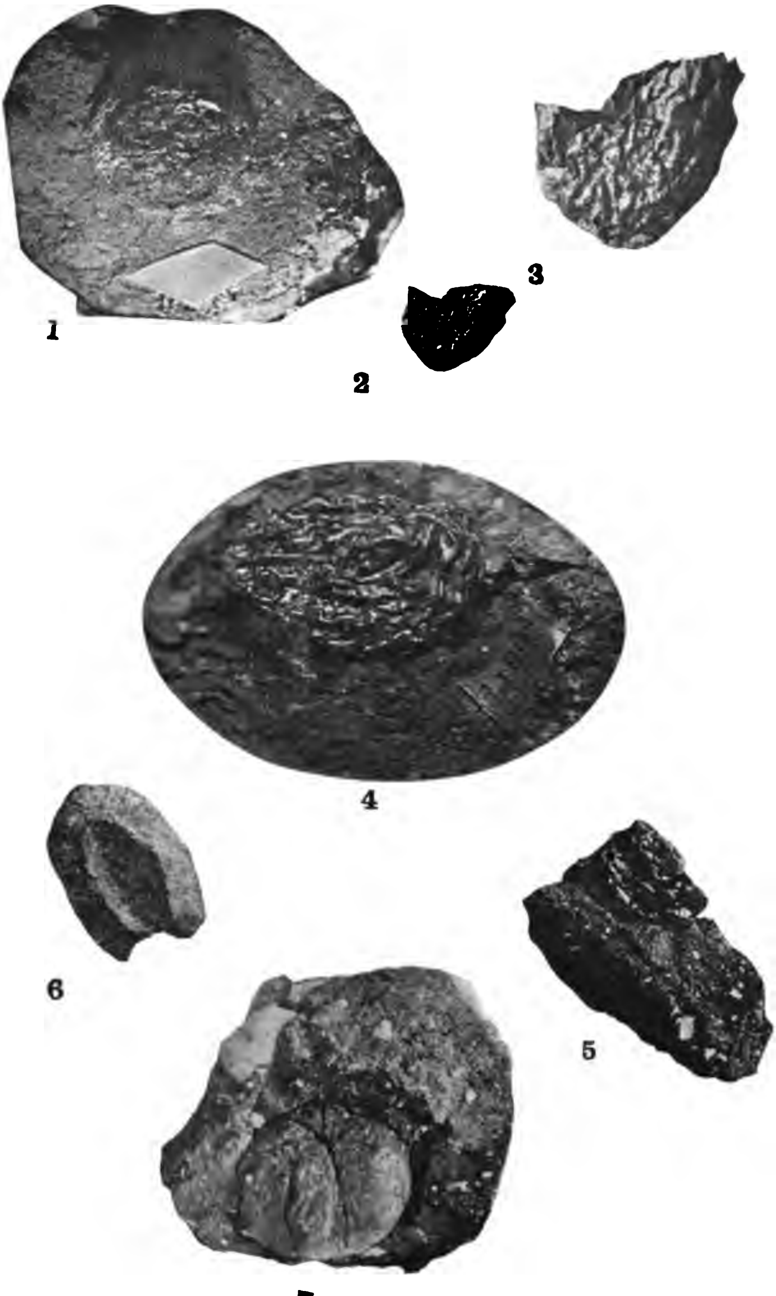
Figure 4. Staphidoides ovalis. (Complete specimen in lignite.) Page 223.

Figure 5. Staphidoides ovalis. Fragment in lignite. Page 223.

Figure 6. Outer shell of fruit.

Figure 7. Apeibopsis heeri, Lesq. Specimen still imbedded in lignite. Page 221.

PLATE LVIII.



Fossils of the Brandon Lignite.

During the summer of 1905, Professor C. H. Hitchcock of Dartmouth College spent a short time in the study of glacial and other surface conditions in the immediate neighborhood of Burlington, and in the short article which follows, he has given a summary of the results obtained. This work was continued and extended both as to time and area explored during the present season.

In the longer paper which follows that on Surficial Geology Professor Hitchcock discusses the Champlain Deposits of the Champlain Valley and Northern Vermont. The experience of the writer of these papers in the field of investigation which they cover renders his work of especial value.

Surfacial Geology of the Region About Burlington.

C. H. HITCHCOCK.

The following is a brief statement of what was learned and of what is sought for in a reconnoisance of the Surfacial Geology of the vicinage of Burlington, September 11-18, 1905.

It is really the investigation of the Quaternary deposits of the Winooski River from Lake Champlain to Marshfield. They are of especial interest because it is possible to study the passage of fluviatile into mariné deposits.

The following altitudes of the river are taken from the Burlington Quadrangle of the United States Geological Survey:

Lake Champlain	95 feet above tide
Winooski River, just below Winooski village	107
Just below dam, east side of trolley, Winooski village	136
Below the gorge of the Twin Bridges	160
Oxbow above this gorge	180
About 1 mile below Hubbell's Mill (near Essex Jct.)	200
One-half mile above Hubbell's Mill	240
Mouth of Alder Brook, Essex	271
Bridge near North Williston	273
At Richmond Village	291

The later discussions will necessitate the statement of the altitudes of the river above Richmond.

Over this section there is a conspicuous high sand deposit, covering a broad area in Williston, Essex, Colchester and Burlington, so situated as to suggest that it may have been a delta of the glacial Winooski River, passing into the remnants of the high flood plain, traceable to Marshfield. At Essex Junction the altitude is 350 feet; but sand apparently coterminous with it caps the hill of 407 feet 1 1-2 miles south, and at 400 feet a little west from the Junction. It is thought that 340 feet expresses the highest altitude of this flood plain in Colchester and Burlington. On the south this height is attained on the Athletic grounds north of the University. On the north this height is adjacent to a limestone ridge, commencing south of O. Golden and extending to J. Q. Adams, in Colchester, these names being found upon the old county wall map of H. F. Walling. In Burlington the plain slopes quickly to the 220 feet level; which is reached at a railroad cut, at the most northern angle of the high plain, and the contour runs southerly to the new Post Office whence it runs to the bluff just east of the railroad union station, and thence northwesterly to the northwest corner of the quadrangle. The sand continues in a narrow strip as far as to the ledges in the Ethan Allen Park, and shows a steep bank towards the Winooski River.

On the east side there are several well defined levels in Winooski Village, and the edges of the higher levels may be followed out to Sunderland Brook on the Mallett's Bay road. North of this brook the plain reappears. The road running directly north from Winooski lies near the edge of the high sand plain, and as it crosses Sunderland brook an extensive deposit of clay is uncovered, underlying the sand.

Five basins have been excavated out of this sand plain. The lowest reaches from the mouth of the river to Winooski Village. The second is of small size, bordered by the ledges in the village on the west and by the rocks underlying the twin bridges on the east. The third is perhaps the most interesting, reaching from the high bridge to Hubbell's Mill. The fourth extends from Hubbell's Mill to the crossing of the river by the railroad east of Essex Junction. The fifth extends from this railroad bridge to the eastern extremity of the quadrangle at Richmond Village, and probably farther to Jonesville. It is presumed that all of these five basins have been excavated out of the original high delta-terrace flood plain by the Winooski River.

It looks as if there had been two additional opportunities for the Winooski to discharge into the old lake (or ocean?), one by way of Sunderland brook to the north, and Potash brook to the south. They suggest tbe branching of a river upon its delta, or they may be simply spill ways for the discharge of surplus water.

Were it not for the presence of several ledges the greater part of this great sand plain would have been carried into the lake, and the several basins described above would have been developed into a single broad valley. The ledges on the west side of the river for more than three miles in North Williston, adjacent to the railroad, have been the means of preserving the great plain of Williston. Ledges with till have protected the Green Mountain Cemetery, while the presence of the red sand-rock at Winooski Village, with ledges now concealed near an old brick yard. may have been responsible for keeping intact the more northern half of the city of Burlington.

In the 1861 Report considerable stress was laid upon the description of the lower terraces of the rivers. It is with the greatest pleasure that we can now better understand the specific origin of the terraces, and to be assured that they are all local; each one being determined by the presence of a protecting ledge, either of rock or of till.

For further investigation two points suggest themselves.

1. What is the precise character of the till and modified drift of the top of the University hill.

2. The more careful study of the marine clays and sands. Every locality should be listed and explored. The first specification because it is desirable to know the location occupied: the second, that additions may be made to the list. Dawson has catalogued 125 or more species of fossils from these deposits from the St. Lawrence in Canada, and certainly the meager list given for Vermont cannot be complete. Then the question arises, do we properly understand the relation of the fossiliferous clays to the sands of the high delta plain? The '61 report says the former underlie the latter. If so, later authors who have written about the Champlain Valley have not properly understood its geological history. I raise another query. There are somewhat elevated regions, as in South Burlington, where the till is a

bowlder clay, indistinguishable from some of the deposits hitherto refered to the Champlain days. Have not these two deposits been confounded together, and consequently the area of the Champlain clays made too great?

So far as the quadrangles of the United States Geological Survey are available, the representation of the Surfacial Geology should devote one color to the areas occupied with ledges, a second to the till, a third to the Champlain clays, besides the terraces, moraines of recession, drumlins, eskers, glacial striæ, and other special phenomena.

UNIVERSITY

The Champlain Deposits of Northern Vermont.

By C. H. Hitchcock.

The views of the older state geologists of Vermont respecting the Pleistocene deposits were enunciated in the quarto report upon the geology of Vermont in 1861. They wrote at an early date before it was generally discovered that icebergs must give way to glaciers in the formation of an acceptable theory to account for all that has transpired since the tertiary period. The various facts concerning the striae, the till, the fluviatile, lacustrine and marine beds were so plainly described, that the glacialist of today will have no difficulty in understanding what was meant, and adapt the statements to present beliefs. By substituting the word glacier for iceberg wherever it occurs, the significance will be clear. It is still proper to employ the term Surface or Surfacial Geology, for the description of "all those geological changes which the earth's surface has experienced since the tertiary period"; and to use the expressions "Drift" and "Modified Drift" there suggested for the materials accumulated by the action of ice and water.

It is my object at the present time to offer a few facts and conclusions respecting the entrance of the ocean into the Champlain valley, especially as connected with the melting of the ice. It was my business in the 1861 report to propose the use of the term Champlain for these deposits and the period of their accumulation. The same word had been proposed by the New York geologists in 1842 for the paleozoic formations situated within the neighborhood of this lake, from the Potsdam sandstone to the Hudson River slates, inclusive. By 1861 geologists had generally abandoned the application of this term to the older rocks, except in a geographical sense, and therefore it seemed to me entirely proper to change the application from the silurian to the pleistocene marine deposits. Almost any geologist in the fifties when talking about these beds would have naturally said "these Champlain clays." It was my object to propose an acceptable word to express jointly these marine deposits and the associated fluviatile sands and gravels constituting deltas, terraces and beaches. The proposal was universally adopted. Quite recently a suggestion has been made to return to the usage of 1842, and apply the term Champlain only to the underlying solid rocks—thus necessitating the adoption of some new appellation for the later period: and I may be excused for recalling certain circumstances pertinent to the discussion.

The official geologists of the Empire State found it convenient to use local geographical expressions for the several subdivisions of the New York system. They could not say sandstone or limestone without some rule. So, instead of speaking of the sandstone constituting the foundation of the paleozoic column which is typically developed in the town of Potsdam, they said *Potsdam*. and not Medina or Oriskany sandstone. The same was true of the limestones and slates. Having named the units of the system they conceived the idea of associating them into groups, and naturally used geographical expressions for the greater divisions; viz.: Champlain, Ontario, Heldenberg, Erie and Catskill. The first included the rocks supposed to border Lake Champlain. All agreed that the Potsdam sandstone was the basal member, but they differed as to the summit. Two districts restricted it by the Hudson river, the third said Oneida, and the fourth Medina or Shawangunk.

Besides the disagreement as to the upper limit, it was discovered that a better standard for the grouping had been adopted by the European geologists who said Cambrian, Silurian, Devonian. These older terms had the priority of application and were employed universally, and it was regarded as superfluous to use the less distinctive geographical New York names.

Furthermore, as time has gone on, there is no correspondence between the New York and European groups. Champlain as defined in the original second and fourth districts belongs to three groups, Cambrian, Ordovician and Silurian; it is not therefore a unit. If Champlain is to be made the equivalent of Ordovician, dropping Cambrian and Silurian, it is the same as the proposal of an entirely different word, and the law of priority will forbid its use. It was such considerations as these that caused the earlier geologists to abandon the application of the term Champlain to the Lower Silurian.

But if the public should demand that the name Champlain shall be used as equivalent to Ordovician, attention should be called to the first term suggested for the Pleistocene beds. All agree that Edward Desor proposed to give tbem a name derived from the River St. Lawrence, in 1850. Three years later the Canadian Survey proposed to use a word of similar sound but different spelling for the oldest rocks, derived from the Laurentide mountains, viz., Laurentian. It was only because the public demanded the use of this word for the Archean to the exclusion of the similar sounding term for the later deposit, that led to the suggestion of Champlain in 1861. A little reflection will show what seems to us a satisfactory modification.

Desor proposed that the deposit receive its name from the River St. Lawrence, but neglected to retain the first part of the expression, and said *Lawrentian*, where the w is retained but the c has been replaced by t. If his attention has been called to the spelling he would have corrected it without doubt: or we may attribute the improper spelling to the proof reader. We can, therefore, claim that the original suggestion means the use of *St. Lawrencian* for the Pleistocone beds, as well as that of Laurentian for the Archean. It is worthy of note that Zadock Thompson used the name Lawrencian for the later deposit in 1853. Hence as at present advised I should say Champlain by preference, but St. Lawrencian if necessary, rather than invent some new designation.

What was included in the Champlain terrane is clearly indicated in the 1861 report. Not only the clays containing the fossil mollusca, but the overlying sands, extending up the tributaries as terraces, at least to the height of the marine limit, were included, the deposits at Burlington were particularly specified as the delta of the Winooski, overlying the marine beds, and produced by the joint action of the river and sea. It was conceived that salt water extended up the several rivers, including the Connecticut, certainly as high as 500 feet, and probably higher, and that the river terraces were deposited in estuaries. The marine remains were imagined to be restricted to the lower levels, because the fresh water above was unsuitable to the well being of the animals, as seems to be the fact today in estuaries. In other words, the formation of the marine deposits, could not be separated from that of the fluviatile accumulations. Later Professor J. D. Dana greatly extended the application of these principles with a better understanding of the character of the ice and the origin of the abundance of water through its melting.

GEOLOGICAL HISTORY OF THE CHAMPLAIN VALLEY.

After the Archean shallow water deposits were formed along the eastern edge of the Adirondack crystallines beginning with the Potsdam sandstone, the whole of the Ordovician terranes succeeded, filling up the valley between the Adirondacks and Green Mountains, and destroying the connection between the waters of the St. Lawrence gulf and the interior sea. Studies of the later faunas show that this barrier prevented the admixture of marine species in later times from European and American sources.

Not to mention the transgression of the ocean in the Medina period into the Champlain basin, and other matters of interest it only needs to be said that the valley was considerably elevated in what is believed to be the later tertiary, and there was a Champlain river flowing northerly. The rocks beneath the lake must have been excavated by running water; and as this flow must have been terrestrial it follows that the deepest bottom must have been elevated sufficiently to allow the river to make its way down hill to the sea. This depth is 402 feet off Split Rock, or more than 300 feet below the level of the sea. This ancient elevation probably amounted to 500 feet or more. It was much later when the river was dammed between the international boundary and the St. Lawrence so as to constitute a lake, the obstruction being the material shoved by the glacier southerly during the ice age.

In my report for 1904 I have described the supposed conditions here in the ice age. Ice came from the Canadian Highlands, filling up the St. Lawrence and Lake Champlain valleys, the central part pushing southerly towards and down the Hudson river and the lateral portions crowding over the Green Mountains on the east and over the Adirondacks on the west. After the long winter was over, melting ensued, ponds and lakes would form where the drainage was obstructed. The highest deposit made in a body of fresh water at this time, so far as is known, was the celebrated beach at Ripton, 2,196 feet above the sea, which was believed to indicate the former presence of the ocean, in the 1861 Report. There must have been many other similar accumulations of sand among the high mountains, while nature was attempting to remove this immense ice sheet by the simple process of melting, sending the water to lower levels. As time goes on more of those high level sands will be discovered and described, the larger rivers will be developed, vegetation will return, and the conditions will become again favorable for human settlement. It will be our task to suggest the development of a few important valleys.

THE HUDSON-CHAMPLAIN VALLEY.

At first, separated by the Green Mountains from the Connecticut drainage, the melted ice will follow the course of the Hudson from western Vermont. Because of its more exposed situation the melting will commence at the south, and the main Hudson river will have an existence while Lake Champlain is still buried in ice. There was much surface ablation to reduce the general thickness, and then the southerly current was developed, perhaps at first seen in the cols or divides between adjacent valleys. In searching for these natural barriers we may first examine the great limestone valley of western Vermont. Hoosic river, passing through Pownal, is separated from the Walloomsac by a divide of 986 feet. Water may have flowed from Bennington into the Hoosic river and carried much sediment with it. Terraces are described in the 1861 Report to the height of 307 feet above the Hoosic; but our information is too meager at present to enable us to speculate as to its origin. Lower down these sands reach the height of 400 feet above the sea, and the delta in the Hudson valley at Schaghticoke is 360 feet high.

The col separating the Walloomsac from the Batten Kill at Shaftsbury is 900 feet high. The latter is the more important, as it rises in East Dorset in a very deep valley between Mt. Eolus and the Green Mountains with the elevation of only 788 feet between it and the beginning of Otter Creek. High sand levels, perhaps moraine terraces, occupy the divide. The delta of the Batten Kill is about 350 feet high at Schuylerville and may be traced for miles up the stream towards Arlington. The col between the Batten Kill and Pawlet river in Dorset is at 940 feet, and evidently played no important part in the history, but without doubt there was a period when water spilled over the East Dorset divide from the Champlain body and contributed to the growth of the flood plain of the Batten Kill.

The next divide over which water might flow is at Rutland, 500 feet, and thence through the gap at Ira into the Castleton and Poultney rivers. Near Whitehall the Poultney and Mettawee rivers, and Wood Creek unite, becoming Lake Champlain, which is scarcely anything more than a river in a drowned valley as far as Ticonderoga.

AUTHORS WHO HAVE DISCUSSED THE CHAMPLAIN HISTORY.

It is important now to state what views have been held concerning the events that have transpired in the history of Lake Champlain. In 1894 Mr. S. P. Baldwin led off in a study of this valley. After the existence of the ancient river and the presence of the ice, he advocated the presence of a "Glacial Lake Champlain," whose waters covered the highest marine limit from one to two hundred feet.* All the later writers cited accept his views.

Warren Upham developed the later history, specifying first the Hudson-Champlain water body, second Lake St. Lawrence,

* Pleistocene of the Champlain Valley. American Geologist Vol. XIII, March 1894

a union of the accumulated glacial waters in the Ottawa and St. Lawrence valleys and Lake Champlain †; and thirdly the incursion of the sea.

Mr. C. E. Peet divides into: 1, Hudson-Champlain; 2, Higher Glacial Lake Champlain; 3, Marine Champlain, partly equivalent to Lake St. Lawrence; 4, Present Lake Champlain.‡

Prof. J. B. Woodworth has elaborately discussed the conditions of the whole area between New York City and Canada in the latter part of the ice age,* paying attention only to what may be seen in New York. He uses the name of Vermont Lake for the body previously called Glacial Lake Champlain, and finds two phases in its history. At first the outlet discharged through the Coville channel near Saratoga, leaving an extensive sandy plain 280 feet above tide. On the eastern side of the Hudson the Batten Kill, at the same latitude, has left a similar high plain near Greenwich, with the altitude of 350 feet. At a later period Lake Vermont discharged through the Wood creek channel above Fort Edward near Whitehall, N. Y., at the present divide between the Hudson and Champlain waters, 147 above tide.

Not to specify others, it is of consequence to learn the figures ascertained by Professor Woodworth at Covey Hill, a conical peak that rose above the lakes on the International Boundary, because similar phenomena ought to appear on the Vermont side. Covey Hill rises to 1,030 feet. The highest point where marine shells occur, 340 feet; the highest marine limit 450 feet; the upper limit of terraces 570 feet; the upper limit of wave action 800 feet. At the "Gulf" near by, there is evidence of a stream of water falling over a cliff at the height of 910 feet. This was supposed to be a spillway adjacent to the ice margin.

Professor Woodworth proposes in consequence of the transfer of the Champlain to the Ordovician to name the Pleistocene

† Bulletin Geol. Soc. Amer., 1892. Amer. Jour. Sci. Vol. CXXIX, 1895.
‡ Chicago Journal of Geology, Vol. XII, 1904.
* Bulletin 84, Ancient water levels of the Champlain and Hudson valleys, New York State Museum, 1905.

deposit, after the Indian settlement of Hochelaga, now Montreal.

THE WINOOSKI VALLEY.

Returning to the discussion of the high level sands, attention will be divided to the three valleys which have cut down through the Green Mountains, the Winooski, Lamoille and Missisco. Salt water from the Champlain ocean could have penetrated the Winooski above Waterbury; the Lamoille as far as Johnson, and the Missisco to East Berkshire. No fossils are to be found, and the rush of fresh waters down the valleys brought with them extensive fluviatile deposits which now figure as terraces.

I stated a few facts about the Winooski deposits below Richmond. The upper limit of the delta was given at 340 feet in Burlington and Colchester. The highest part of Burlington, 418 feet, must have been covered by the waters of glacial Lake Champlain, thus accounting for strata of sand peering above the delta up to 380 feet south from the University. There would seem to have been a water worn cliff on the north side of the Fletcher Hospital, and another southwest from the highest hill in the city, near Mr. Holt's residence.

There must have been an inflow of water into the Winooski from the west flank of Mt. Mansfield. Brown's river now curves northerly at Jericho and passes through Essex and Westford to the Lamoille in Fairfax, but the removal of a few feet of light material would enable it to pass south from Essex through Alder brook to the Winooski. From Underhill through Jericho the slope is slight and the terraces are spread out without much thickness. Behind the railroad station at Underhill Flats the terrace may be 40 feet high. At Jericho Corners the terrace is 540 feet high, and passes into the upper flat on Lee river, a tributary from the southeast. In this there is a marked spillway twenty feet lower, 25 feet above the water in Lee river, which would have allowed much water to escape southerly near the west line of Jericho. Below a rocky knob the Winooski sand reaches up gradually to 520, 540 and 550 feet. It seems clear then that Brown's river assisted in the accumulation of the Winooski flood plain, and that its course was changed to flow into the Lamoille by the deposition of sediments that blocked up the natural outlet.

Higher up there is a hill showing blown sand conspicuously, 750 feet high on Mill brook in the southwest part of Jericho. What has the aspect of a marine beach encircles Richmond pond three miles north of Jonesville, estimated to be 590 feet high. Saxon Hill rises to 900 feet and exhibits indications of considerable washing by waves, for large bowlders stand out numerously above the till, in which they were once imbedded; and as the result the surface of the ground is uncomfortably rough. On its western side may be seen the high sand plain with the height of 506 feet out of which Alder brook has carved its channel between Essex Center and the neighborhood of North Williston. The angle of this sand plain that touches the Winooski is a good illustration of the protection afforded by ledges to overlying loose material. The locality is about a mile east of the high railroad bridge over the Winooski.

Between Essex Center and Essex Junction the railroad passes over a ridge of till about 150 feet higher than either village. From the Junction the high sand terrace is traceable northerly to Colchester station and to north of the village, as well as to the spillway of Sunderland brook.

The modified drift of the Winooski above Jonesville is disposed like a high fluviatile flood plain, the upward continuation of the delta. It seems to rise gradually to 767 feet at Plainfield and to 870 feet in the south part of Marshfield. The thick deposits of clay above Montpelier belong to it. Doubtless the unusual quantity of modified drift in the Winooski valley came from a terminal or recessional moraine of the ice sheet traceable from Willoughby lake along the northern edge of the hydrographic basin, through Walden, Woodbury and Worcester.

A high level gravel is apparent on both sides of the gap between Waterbury and Middlesex. The col is estimated to be 1137 feet high, and the gravels at 960, 250 feet above Waterbury Center. Near M. Turney's in Waterbury (Beer's Atlas) is a delta, bisected by a small stream, formed when the glacial waters stood at this height. Our figures are approximate, and therefore this high level delta may have been formed when the waters of the Winooski, even earlier than the Glacial Lake Champlain, were prevented from following their natural outlet and were emptied into the Connecticut basin through the Williamstown gap 908 feet. The outlet through Roxbury, where the Central Vermont railroad finds its way, has the altitude of 1016 feet: and it is a significant fact that the fluviatile deposits are far more abundant through Brookfield, East Randolph and Royalton than through East Granville and Bethel; and they would seem to imply the existence of a glacial stream through the Williamstown outlet from the impounded waters of the Winooski. The other low places in the divide at Washington, and at Warren are considerably higher than the summit at Roxbury, and so far as known, no considerable fluviatile deposits seem to have been made by the early glacial waters in connection with them.

CONNECTION WITH THE LAMOILLE VALLEY.

The lowest col between the Lamoille and Winooski basins is near the line of Morristown and Stowe, 745 feet, in a large swamp. Waterbury river rises on the east flank of Mt. Mansfield, descends to this swamp and then feebly gathers itself together for the descent through Stowe and Waterbury. There is not as much as ten feet of barrier to turn the waters from joining Joe's brook and flowing to the Lamoille at Morristown.

My attention was directed to this interesting locality in 1895, when I discovered a singular ridge of cobblestones running very near the town lines of Stowe and Morristown. Upon investigation, it is evident that this ridge, not so very unlike an esker, had some connection with the glacial waters moving from the Lamoille to the Winooski. The swamp and intervale is about three hundred rods wide, converging to an angle at the village of Stowe. It has on its borders, first, a low terrace of about twenty feet altitude, and a second one showing itself in the edge of the village seventy-five higher, all of sand. The plain of the village, 720 feet, is at the level of this low terrace. It is hard to be convinced, on looking northerly from the village, that the water does not flow towards Morristown, because there is a rocky barrier to the south. On reaching the lowest point in this barrier the Waterbury river is seen to flow through it in a deep gorge, so that one can easily divine the situation. The Lamoille waters were kept in by a rocky barrier as much as a hundred feet higher than it is now, when the higher sandy terrace was deposited, and perhaps the pot hole on Sunset hill east of the village and 150 feet higher, with the diameters of 44 and 39 inches was chiseled out at this time.

The continuation of erosive action by the waters flowing over the rim excavated the gorge, and now the Waterbury has an unobstructed passage from the slopes of Mansfield, and the lowland of Stowe, to the Winooski. The water in the gorge must have an elevation of about 700 feet.

The Lamoille valley is noted for its enormous piles of modified drift. Commencing in Hardwick, they reach the altitude of 380 feet above the river in Wolcott, and ascend to 200 feet up the east branch in Elmore. In Hyde Park and Morristown the sand is spread out broadly to as great heights above and below, over low lying ledges. In Johnson the sand reaches altitudes of 190 and 277 feet above the river. In Cambridge the normal high terraces are fully 100 feet above the river. The valley is broad, and there are signs of sand deposits much higher, toward Fairfax. All these and others represent the ordinary terraces, made when the Lamoille river confined its labors to its own proper limits.

Observations along the southern margin of this basin have brought to light some remarkable high level sands. At Walden these sands reached to the altitude of 1331 feet, 450 feet above the river at South Hardwick. Up the east branch in Elmore they extend to 1,055 feet. Elmore pond is at about the level of a very high sand plain passing through Morristown into Stowe. At the Flat mountain view farm, and at J. E. Huse (of the county map), this plain reaches 1,007 feet. It may be followed continuously at about the same elevation on the west flank of Elmore mountain to the north line of Stowe, at H. C. M. Sherwin, (Beer's Atlas) where it measures 1,120 feet. The ground falls away to the west along this town line, displaying at first till, with coarse stones below the sand, and then the curious ridge of gravel and cobble stones, along the divide, already mentioned. The opposite sides of these valleys have not been examined for these high level strands. Some light as to the origin of these sand deposits may be obtained after a study of the Memphremagog basin.

THE MEMPHREMAGOG BASIN.

At the present time the limits of the Memphremagog basin may be easily outlined, so far as Vermont is concerned. The first adjoining stream on the east at the International line is the Tomifobia, only three miles distant, and the dividing ridge may be one hundred feet above Memphremagog, which stands at 695 feet above the ocean.

The railroad has a station here, Lineborough. The ridge may be followed to Island Pond southeasterly, where the watershed is 1,120 feet. Here it turns abruptly to the southwest, and presently reaches the top of Mt. Pisgah, 3,793 feet. Next is Willoughby Lake 1,155 feet, and a divide of 1,246 feet. Mt. Hor on the west may exceed 2,000 feet. Then the line descends to the summit level of the Passumpsic railroad, 1,214 feet. The land is much higher in Sheffield, leading to the southern rim of Runaway pond in Glover, 1,284 feet. Passing through Greensboro, Elligo pond is reached in the west corner of the town, the lowest level in the whole rim, 893 feet. Above the pond I have recorded two shelves, 933 and 1,015 feet. Beyond Elligo pond the border rises through Craftsbury to Lowell, and then runs northeast near the lines of Irasburg and Coventry to the ridge in Newport west of the lake 1,273 feet. This ridge separates Memphremagog from the tributaries of Missisco river. In Quebec the basin is much narrower than in Vermont. The three principal tributaries, the Clyde, Barton and Black rivers, all flow northerly and reach the lake at Newport. Barton river has its source in Runaway pond, and Black river in Elligo.

GLACIAL LAKE MEMPHREMAGOG.

In 1894* I announced the discovery of three elevated sand and gravel beaches in the hydrographic basin of Lake Memphremagog, approximately 970, 1,060 and 1,270 feet above tide water, referable to an ancient glacial lake. The lower strand does not extend so far north as Owls Head in Quebec, on the west side. In Newport it was recognized on Prospect hill and on the east side in Salem. In the 1861 Report high level sands were described as lake terraces, at the altitudes (as corrected) of 1,060, 1,071 and 1,274 feet, the last two being on the east side in Salem. The conspicuous flat, capped by a cemetery in West Derby seems to belong to the lowest level. On the west side of Black river in Coventry, another of these levels has been recognized, capped by a layer of cobblestones.

At Beebe plain the Tomifobia river is only 80 feet above Lake Memphremagog and soon reaches a lower level. East of Libby's mills, Stanstead, the lowest of these beaches may be recognized, and the other two may be seen in passing easterly. There seems to be one or more of these beaches on Bunker Hill on the northwest side of the Tomifobia to the southwest from Lake Massawippi.

Upon Barton river three levels were observed at the heights of 1080, 1180 and 1284, and were recognized as something different from river terraces, principally because they did not follow the slope of the river.

It is only quite recently that I discovered that the outlet of Glacial Lake Memphremagog must have been at Elligo pond and that there was some correspondence between the levels there noted and the abundant strands left by the melting of the ice. The two lower Memphremagog levels correspond roughly to the beaches at Elligo pond ; and the highest one to the altitude of Runaway pond, and possibly to the divide at Willoughby Lake. Other coincidences will be apparent.

The discharge of Glacial Memphremagog into the Lamoille explains the enormous accumulations of modified drift there. The various levels near Stowe have also some relationship to

* Bull. Geol. Soc. Amer. Vol. VI.

the Glacial Memphremagog strands ; so that it is conceivable that at one time Glacial Lake Memphemagog discharged through the Elligo outlet into the Lamoille, and the Glacial Lamoille discharged through the Stowe strait to the Winooski, and even this latter stream poured through the Williamstown gap into White river, and eventually into the Connecticut. This condition of things could prevail only when the ice filled up Lake Champlain so high that there was no chance for the water to be discharged except through an eastern outlet.

THE DELTA OF THE LAMOILLE.

The copious fluviatile deposits brought down the Lamoille seem to terminate in Fairfax. For a mile or two above the town to the south at East Georgia, terrace relics are very scanty. It is possible that the powerful stream may have scoured out the valley and transported the sediments to what is usually termed the delta in Georgia and Milton. The sand plains of these two towns reach the altitude of over 400 feet and occupy much of the space between and around two conical hills known as Snake and Cobble. It has been conceived that these hills were islands in the Champlain marine estuary, and would carry upon their sides the marks of the different levels attained by both the glacial and marine overflows, and that the upper marine limit might be ascertained with great precision upon them.

Snake Hill is 912 feet above the tide, and about 100 feet above the plain upon the west and south sides there is a shelf in the rock that may have been carved out by wave action. The ledge rises precipitously above this shelf, and has been cut into at the base sufficiently to suggest a sea wall, especially upon the west side, which was particularly exposed. There are many blocks of stone that have fallen from the cliff so as to lie upon this shelf. On the east side there is a less pronounced shelf at the height of 560 feet, also at the base of very steep ledges. The upper shelf is at a point in the rock where there is an anticlinal in the quartzite, and therefore may have been determined by the stratigraphy. Between the hill and Milton village there are many ledges lower than the surface of the plain which suggest the action of waves.

In studying Cobble Hill the phenomona are equally distinct, but more diversified. The high plain reaches from Milton around to Checkerberry Village, and is there interrupted by a ledge to the north of the village, and by till to the south, and southeast towards Cobble Hill. This ridge has prevented the spreading of the sand to the southwest, and consequently the area of the delta is more restricted than was represented in the report. And it is not confluent with the high delta of the Winooski. It is underlaid by clay, and marine fossils are found on it. There is a marked lower level in the lower edge of the plain at 270 feet. The low delta now forming at the mouth of the river has been fully described in the 1861 Report.

On the southeast side there is a series of steps that illustrate the history of the neighhorhood. On Malletts' Creek where it crosses the town line the marine clay is exposed for the height of 40 or 50 feet, the lowest limit visible being 236 feet. It is capped by a gravel beach 30 feet thick. The materials include many fragments that have been transported many miles. This beach was first noticed near the house of N. Austin, (old county map), and continues a quarter of a mile to the house of A. E. Lamb, and crosses the field east of his residence to the base of a lenticular hummock, very suggestive of a drumlin in its shape—it contains ledges. The level is 316 feet, and corresponds to that of the railroad crossing a mile to the south. Passing up Cobble Hill, four benches are recognized, at the heights of 446, 460, 566 and 586 feet. The land is cleared for pasturage up to the highest shelf where it is replaced by forest growth, and a steep ledge, suggestive of wave action. Cobble Hill is 827 feet high, and the 566 feet level is the one best defined; and it may be recognized on the high land to the southwest, and upon the west side; in this last locality it was noted from Snake Hill.

A pocket level indicated the same altitude of 586 feet upon a hill two miles south. east of the house of E. T. Skinner. On going there the barometer confirmed the level. Above it ledges of slate have been cut apparently by wave action, and there is a lower shelf also, corresponding to the 566 feet level on Cobble Hill. Other hills high enough to show these shelves, are situated east of the railroad, either in Colchester or Essex, but I did not have time to visit them.

OBSERVATIONS AT ST. ALBANS.

A day was spent in searching for Champlain fossils and high water levels at St. Albans, with fruitful results. Mr. G. E. Edson showed me a shell, *Yoldia obesa St.*, in clay, which he had taken from the ground in Stevens brook, near the Week's farm and School House No. 1, with the altitude of fully 575 feet. This is higher than anything ever before reported for Vermont, and even exceeds the accepted figure, 560 feet, for Montreal, though not equal to the upper marine limit there of 625 feet. The highest well authenticated localities of these shells has hitherto not exceeded 300 feet in Vermont.

Other levels apparently made by water were 505 feet at the intersection of Barlow and Fairfield streets; 605 feet east of S. H. No. 1; 740 feet, the base of a cliff near the residence of Governor Smith on Aldis Hill; a flat gravel area at the same level at J. H. Brainerd's. This same level apparently is found at Mrs. Revoir to the east of J. H. Brainerd, and at the west base of Prospect Hill near the south line of the town. Still higher is a shelf in the till at J. Sullivan, on the Fairfield road, 890 feet. Because it is the highest one noted, it is less satisfactory than the others.

None of these rough measurements agree with the observation of Baron de Geer, who found the highest marine limit at St. Albans to be 658 feet, not based upon this occurrence of shells. Mr. Baldwin saw no marine limit here above 500 feet, and he concluded that the Baron's observations must have related to one of the higher levels of the Glacial Lake Champlain. The fossil and the higher levels discovered are situated in what must have been a cove, open to the south, between Aldis Hill and the Fairfield road.

In New York, nearly opposite St. Albans, Professor Woodworth found evidences of wave action, in Altona and near Cannon Corners, at 640, 660, 675, 705, 710 and 750 feet. Hence there is a general correspondence between the old water levels of Glacial Lake Champlain in both Vermont and New York, near the International Boundary.

DIFFERENTIAL CHANGES OF LEVELS.

It is now well established that the land does not rise and fall uniformly over large areas. In the 1861 report it was held as an axiom that the whole continent rose or fell uniformly, as a mass. But the see-saw movement had also been recognized, where one part rose and the other fell, like a plank operated by young people in their sports, upon the two sides of a central axis. Today, illustrations of this differential motion of the land are being discovered all over the world.

Along the Hudson Champlain valley a movement of this kind has long been recognized. The hinge-line is conceived to be at the mouth of the Hudson, and the greater changes to lie in the St. Lawrence basin. The cause of the original depression has been ascribed by some to the weight of the ice sheet. The greatest thickness of this substance must have been in the St. Lawrence valley, and when the pressure was taken off by the melting of the ice, the land would respond and spring back again.

The determination of the amount of these changes of level is effected by studying the altitudes at which the marine fossils have been found, with which the early glacial levels should correspond. Thus, near Vergennes these shells reach to 250 feet; at Burlington to 297 feet; at St. Albans 575 feet; the more northern localities are the higher, but when the ocean was present, the Vergennes, Burlington and St. Albans beach lines were at the same level. There is besides the comparison of the upper marine limit, which can sometimes be determined more readily. The animals occupied different levels at different times not easily correlated, but there ought to be some differences in the aspects of the oceanic and fluviatile depositions.

Suppose a study be made of the deltas of all the streams flowing westerly on the east side of Lake Champlain. It will be seen that the deltas of the Poultney, East Creek in Orwell, Otter Creek, Lewis Creek, La Plott river, Winooski river, Lamoille river and

Missisco river have each a higher level than their predecessors. A line connecting these several summits when compared with the distances will show how great the rise is for each mile. It has been stated to be one foot to the mile, and three and four feet to the mile according to the localities. The variation per mile is greater in the lower than in the upper Champlain waters.

I have said nothing of this differential elevation in the early part of this report, but it will be obvious that in comparing the heights of the two shelves at Elligo pond, 933 and 1,015 feet, with the glacial strands on Lake Memphremagog, 970 and 1,060 feet, the more northern altitudes should be higher than the others. The reader may bear the same variation in mind in his comparative study of the levels in different parts of the State.

CONCLUSIONS.

1. The proper geographical expression for the marine Pleistocene terrane is Champlain or St. Lawrencian.

2. It is preferable to say Glacial Lake Champlain, Glacial Lake Memphremagog, and so on, than to use other geographical terms less easily applied.

3. Glacial waters commenced to accumulate as soon as the ice began to melt, and may have passed from one hydrographic basin to another when the natural outlets were obstructed for any cause. Such may have been the flow from the Otter Creek basin to the Batten Kill or the passage of the Winooski waters to the White River Valley via Williamstown.

4. Glacial Lake Memphremagog discharged through the Elligo pond col into the Lamoille valley, and was tributary to Glacial Lake Champlain.

5. Glacial Lake Champlain, may have been from 200 to 300 feet higher than the marine limit.

6. It is easier to invoke the glacial dam to account for the various Pleistocene beaches, benches, wave-cut notches and sea cliffs than to appeal to changes of level.

The Drinking Waters of Vermont.

G. H. PERKINS.

INTRODUCTION.

In the last Report there was a brief account of the character and sources of the water used for domestic purposes in this State. At the time the Fourth Report was issued it was impossible to publish more than the few pages which those interested will find there.

For the present Report not only is the very considerable accumulation of material obtained for the previous Report available, but during the last two years, much and important additional information has been gained. It is therefore possible to discuss the subject more fully and more accurately than heretofore.

The writer realizes the inevitable tediousness of too much detail,and yet without details it does not seem possible to treat the subject with the completeness that it deserves. It is not expected that everyone will be interested in all the tacts herein stated, but it is the hope of the writer that every one will find enough that will attract his attention to convince him of the value and importance of such investigations as those which have afforded the results given.

Primarily of importance to the residents of the State, these investigations are also useful to those who, though now living elsewhere, may have some thought of making either permanent or temporary homes in Vermont. The tendency of many city dwellers is towards the country, at least for the summer months, and that region which can furnish an abundance of pure and palatable drinking water will always be most likely to secure the patronage of migrants from the city.

I think that the facts given in the following pages show conclusively that few, if any, parts of the country are as well supplied with good water as is Vermont. Moreover, the location of hundreds of constantly flowing springs is such that it is not within ordinary possibility that any sources of contamination will arise in the future.

As stated in the previous Report much valuable assistance has been received from the Division of Hydrology of the United States Geological Survey and especially from Mr. M. S. Fuller, Chief of Eastern Division.

Obviously, the most thorough investigation of the water supplies of Vermont would be made by personal visitation of all parts of the State, but however desirable such examination of the entire area under discussion may be, it has been quite beyond the range of what was possible. Most of the larger towns have been visited and direct information obtained, but for most of the smaller towns all that could be done was to make such inquiries as seemed necessary by mail, and from individual residents when there was opportunity. This has been done as thoroughly as possible during the past four years. On this account it is to be noted that the accuracy of many of the statements given must depend almost wholly upon the correctness of the replies which have been received from Post Masters, Town Clerks and others who have in most cases very helpfully and cordially assisted in the work. In this way sooner or later nearly every town in the State has reported and in many cases a number of reports from different persons in the same town have been obtained.

To Vermonters some of the topographical and geographical features here noticed will seem quite familiar and therefore unnecessary, but it is thought that these are likely to be helpful to those without the State who are more or less unacquainted with facts that are well known to the residents of this region.

Besides the sources of information mentioned, the writer is greatly indebted to the last two or three reports of the State Board of Health and to the State Laboratory of Hygiene for information not gained elsewhere.

Vermont contains 246 towns and 8 "Unorganized towns." Of these 254 towns 168 are wholly, or largely, supplied with water from flowing springs, 39 are supplied about equally by springs and wells, 31 mainly by wells, 9 by water from lakes or ponds, 7 by water from streams. Many of the towns reported as supplied by springs might be said to take their supply from streams, but these are brooks running directly from springs so that the water is practically spring water. As the term is here used stream means only a river far from its sources so that its water is in no sense spring water.

In the following table will be found analyses, most of them made at the State Laboratory, of the water now drunk in quite a number of the larger towns of the State.

It may be said by way of explanation that the "Total Solids" means the sum of the mineral or organic solid matter held in the water.

"Fixed Solids" are those that remain after burning off the organic matter and the loss of whatever inorganic may be volatile when heated. The "Albuminoid Ammonia" is that present in organic combination, while "Free Ammonia" is that which is not in combination. The quantity of ammonia whether albuminoid or free, is not necessarily a sure indication of the purity or impurity of water, but still, a high percent of ammonia, especially if there is much chlorine with it, indicates serious impurity and the need of immediate attention to the source of supply. In most water analyses the amounts of nitrates and nitrites are given, but these are so small in most Vermont water that they may be usually neglected as of no importance.

Table Showing the Chemical Character of Drinking Water in Vermont.

Each analysis is the average of at least three taken at different sections. The figures indicate parts in 1,000,000.

Locality.	Source.	Total Solids.	Loss on Ignition.	Fixed Solids.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Hardness.
Addison	Wells	82.57	10.77	71.80	10.773	.0022	.00102	44.
Alburg	Wells	70.22	12.72	57.50	.071	.0398	5.01	15.
Barre	Brook	101.	10.8	90.2	.090	.085	11.	90.
Bennington	Springs	28.18	11.6	17.2	.008	.065	.5	15.8
Bradford	Brook	102.5	22.	82.5	.006	.028	.73	85.2
Brandon	Pond	98.3	30.	68.3	.066	.162	.173	74.6
Brattleboro	Springs	106.5	22.5	84.	.007	.033	2.5	80.9
Bristol	Spring	152.3	33.7	11.96	.010	.009	.6	105.
Burlington	Lake	64.8	11.16	53.64	.086	.105	1.	50.9
Canaan	Springs	73.5	14.1	59.4	.013	.070	.47	57.5
Chester	Brook	35.	10.6	34.4	.010	.075	.8	20.
Hardwick	Brook	196.6	20.	86.6	.076	.084	.66	84.
Island Pond	Springs	42.	15.7	26.3	.066	.085	.4	23.9
Johnson	Brook	25.	14.6	10.4	.008	.900	.4	15.9
Lyndon	Springs	14.7	8.17	6 53	.018	.031	.6	128.
Middlebury	Springs	58.5	14.7	43.8	.007	.078	56	42.6
Middlesex	Springs	25.	7.3	17.7	.08	.031	.33	14.
Morrisville	Springs	59.06	11.5	48.1	.006	.030	.6	46.1
Newport	Pond	119.	22.	97.	.126	.157	1.08	94.7
Northfield	Springs	112.	14.	98.	.007	.031	.5	88.6
Randolph	Springs	192 5	22.	80 5	.006	.028	.73	85.3
Readsboro	Brook	37.	11.	26.	.021	.010	.73	27.
Richford	Springs	48.8	16 6	32.2	.014	.100	.66	30.3
Rutland	Brook	56.6	18.5	38.1	.011	.111	.53	34.
St Albans	Brooks	49.8	16.	33.8	.016	.174	.7	38.4
St. Johnsbury	Pond	52.5	20.	32.5	.006	.141	.67	34 1
Stowe	Spring	71.	17.6	53.4	.007	.036	1.7	58.6
Underhill	Springs	60 3	14.	46.3	.010	.051	1.5	47.8
Woodstock		45.1	16.3	28 8	.33	.093	1.53	55 3

The above table, as will be noticed, is mostly made up from public supplies. This, however, is no detriment to its representative character for by far the greater portion of the population of the State drink water from the sources given in the table. As has already been mentioned wells are used by many, but not nearly as many as use water from springs, brooks or ponds. Wells, even when located near each other, vary so greatly in all respects that no averages of any value are possible.

The records received in answer to my inquiries show that a much larger number of towns use spring water than that from any other source. For obvious reasons, spring water is not available in the larger towns, but in the more sparsely settled parts of the State spring water is far more commonly used than water from wells or streams. Of course, there are many localities where wells, deep or shallow, cisterns, streams, ponds or lakes, can be most conveniently and economically used and therefore the people take their supplies from one or more of these sources.

Most fortunately, however, in a large part of the area of Vermont springs not only furnish the purest water, but it is cheaper and easier to get it from them than from any other source. The State is full of hills and the hills are usually full of springs, and because of this abundance of spring water and the economy of piping it from its source to places where it is needed some sort of public supply is found in many places of small population where under ordinary conditions such systems would be too costly and would not be established. In many cases the public supply is owned by the town in which it is located, but quite as often it is owned by some sort of a company or by an individual. It is also a consequence of the prevalence of springs that there is not only a public supply, but several of them in even small towns. There may be only two or three systems or there may be more, even as many as ten or twelve. Each system may supply from two to several hundred families.

Whether the water supply or supplies of a town are public or private if the water is used by more than ten families the State Board of Health request that it be sent to the State Laboratory for examination at least once in every three months. More than this, if at any time a health officer considers it necessary, a sample must be sent forthwith. In a late Report of this Laboratory it is stated that "The systematic examination of the public supplies of the State is being carried on at the different seasons of the year and, with few exceptions, the towns are taking advantage of this opportunity of watching the condition of their water supplies."

There are at present more or less public water supplies in over 80 of our towns. When it is remembered that Vermont is eminently a state of small towns and that the population as compared with other states is not compact, but scattered this number is very creditable.

As in most parts of the State the rocks are not soluble to any great extent it follows that most of the spring water is soft. In the Champlain Valley and a few other areas of limited extent there are beds of limestone and here the water is usually hard. The wells, too, of many portions of the State furnish soft or at least not very hard water, but as a rule the well water is much harder than that from other sources. The more superficial currents, those which most frequently give rise to springs, do not appear to reach so much soluble mineral matter as do the deeper currents from which the well water comes. Most people instinctively prefer spring water to any other, although in some cases where the springs are of shallow origin and therefore grow warm in summer, they may be temporarily deserted for wells. It is, however, surprising how cool the water of many springs is throughout the summer.

The very fine and large spring in Stowe Notch registered 39° in August and other springs in different parts of the State are reported as remaining nearly constant in temperature through the year. Most of these are not far from 40°, it may be a little more or a little less. In Water Supply Paper, No. 110, Professor T. N. Dale says of the water of the southern half of western Vermont. "Some of the water is unusually cold. Three fourths of a mile northwest of the top of Dorset Mountain and 1700 feet below it, in the township of Danby is a brook of crystal purity, in which the temperature on September 22, 1891, was but little above that of ice water. Ice-water springs also occur occasionally at the foot of exposed sun heated slate quarry dumps in Washington County, N. Y., in places where no mountain drainage could possibly come. These springs maintain a low temperature throughout the hot summers. Another brook of low temperature known as Cold Brook, occurs 3½ miles southeast of Dorset Mountain in Dorset Hollow. On July 20th, a very hot day, it was cold enough to form a mist about itself. It issues from a limestone cave, through which its course lies and which is at times, presumably, more or less filled with snow and ice."

It is scarcely necessary to say that all over the State, the water of Mountain Springs, or of brooks which have only recently been formed from them, is uniformly cold in summer and does not freeze in the coldest weather, that is, is nearly constant in temperature through the year.

The above applies to surface springs, that is those that break out at the surface, but of course the same may be said of wells though this is not so remarkable since wells are always expected to furnish cool water.

An interesting explanation of the cold water of these springs has been suggested to me by a friend who is a very acute observer of natural phenomena. This is substantially as follows: Along many of our quartzite and other ledges there is often a very large bank of talus, broken rock which has been cracked off from the solid portions mainly by the action of frost. This, from the nature of the case, is not very compact, but contains numerous and not seldom large, cavities made by the irregular piling up of the rock fragments. Indeed, the whole mass is loosely piled together, at least this is usually true. Into such a mass air would readily find its way and even considerable currents would now and then pass through. During the warm weather of summer, this air below the surface, especially when shaded by the rocks, is cooler than that above, i. e., than the general temperature of the locality, while in cold weather the outside air would be colder. Cold air being heavier than warm, in summer the cold air would remain in the lower cavities of the rock mass, while in winter the cold surface air would sink into them driving out whatever warmer air there might be in them. Under such conditions the ice formed in the winter would remain unmelted much longer than outside and in exceptionally favorable localities might not wholly melt.

Now it is easily seen that springs arising near such places or streams flowing through them would be cooled much below the temperature they would ordinarily have. It has been noticed in some places that after an exceptionally warm day or days some streams always increase in volume. This would indicate that melting ice added to their usual supply. It would also appear to be true that a part of the constant supply came from the slow melting of ice masses that had accumulated during the previous winter.

By far the larger part of the wells in use in this State are the ordinary shallow sort, though the number of deep wells is constantly increasing since some are drilled every year. The common wells are not ordinarily more than 30 feet deep and more often less, that is 15-20. In other words by far the larger part of these ordinary wells are in the drift which covers nearly the whole State. Driven wells, and especially bored or drilled wells, are often much deeper, and go down far into the rock which underlies the drift. How many of these deep wells there are in the State I am unable to say with exactness, but there must be over a hundred which are more than fifty feet deep and most are over a hundred feet. The deepest well is one in Shelburne which goes down 1400 feet but has no water. There is another in Bennington 1,255 feet deep which is also useless for the same reason.

In only two or three cases does water flow from the wells. In most it does not rise nearer the top than 30 feet and in many not as near as this. Deep well pumps, the Pohld air system or some such device is used to bring the water to the surface. Deep wells are most common in the Champlain valley and end in Cambrian or Ordovician strata. The total amount of solid matter is usually greater in the water of deep wells than in others.

Vermont is not rich in mineral springs. As in many other regions, there are many so called mineral springs, that is they have a slight taste of iron or sulphur or other substance, but not enough of mineral content to entitle them to be classsd as truly mineral springs.

I judge that there are some twenty springs in the State that may fairly be called mineral. At present only six of these localities are patronized to any extent outside of their immediate vicinity. These are Alburg Springs, Brunswick, Clarendon, Highgate, Middletown, Newfane and Sheldon.

Analyses and other information as to these springs will be found in the following pages under the town in which each is located.

At many of the above localities, spacious hotels have been erected and they are popular summer resorts. From most of the springs named, water is shipped. In many of these places there are several springs, which may be similar or may differ from each other more or less.

In the following pages each town in the State is named and a brief account of its water supply is given. Both counties and towns are arranged alphabetically.

Reports from the Towns of Vermont as to the Source of Drinking Water.

ADDISON COUNTY.

This part of the State lies between Lake Champlain and the main range of the Green Mountains. In the eastern part of the county there are irregular ridges some of them over 100 feet high and a portion of the western flank of the mountain range is included in the area of the county. Naturally, this part of its area is rugged. The western portion, that which borders Lake Champlain is nearly level the slope being west or toward the lake. The main drainage of the region as a whole is northward chiefly through Otter Creek, which extends from south to north through the middle of the county. The whole area is thirty miles from north to south by thirty-three miles from east to west, and covers about seven hundred square miles. The rocks vary greatly in character in the eastern and western parts of the county. Along Lake Champlain and for some distance east they are stratified. limestones and shales. Farther east is a belt of red sandrock and then most of the rocks are schists and gneisses. There are in this county twenty-three towns.

ADDISON. This is one of the lake towns with a fairly level surface. The prevailing rock is limestone or shale though there is also sandstone. Springs are less abundant than in most parts of the State and water must be obtained mainly from other sources. The well water is always hard and not seldom unsuited for household purposes on this account. Yet wells are used as a source of supply more than any of the other sources. In the immediate vicinity of the lake its water is often obtained by windmill pumps.

Mr. F. W. Fisher writes from West Addison: "Our water is one of the serious questions of our farmers. In this part of the town very few have an adequate supply except those whose farms lie along the lake shore. There are very few springs in this region. There are deep wells operated by windmills and they seldom fail Most families have cement cisterns and use rain water for drinking and domestic purposes as all wells give hard water.

The eastern portion of the town lying along the fringe of hills is pretty well supplied with spring water which often tastes of salts of iron."

Mr. Vanderhoof mentions a mineral spring in this town which contains calcium and magnesia sulphates, magnesia bicarbonate and iron, but the water does not appear to be used except locally.

BRIDPORT. Of this town Mr. D. H. Bennett writes: "Every farm has one or more ordinary wells. My village home has three. The wells are of various types. Some are piped, i. e., bored and followed up by tubing, but most in this vicinity are dug and stoned up. There are some deep wells bored in the limestone, the water being raised by windmill."

BRISTOL. This town has had for some years a public supply which is taken from two springs north of the village and the water of a third spring is pumped into a reservoir 150 feet above the village where it unites with the rest of the supply and is thence distributed by gravity over the town. Private springs are common in the region and many are used. Wells also are used to some extent. These are mostly shallow. Mr. H. Bates has a well 92 feet deep, 6 inches in diameter. The water is 40 feet deep, thus coming to within 52 feet of the surface. The water is hard and is raised by a pump. In drilling this well, 20 feet of surface soil and 72 feet of marble were gone through. The well water is hard. In April, 1905, the town voted to install a new supply which is to be taken from what is known as the Seth Hill brook on Lincoln Mountain. The place from which the water is taken is five or six miles from the town and 1,170 feet above it. The brook is a large one and the water of the purest. Indeed, few towns can boast of such a water supply as this affords. When I saw it, the water was somewhat high, as it was in April, but it is said that in midsummer the volume is still large, far more than Bristol can use. It is stated that by measure, when the water was not at its greatest amount, over 2,000,000 gallons daily ran through the measuring apparatus.

CORNWALL. Most of the residents of this town appear to use wells, but a few have springs. The wells are from 15-30 feet in depth.

FERRISBURG. Springs are found to some extent in this town, but are reported "as not much developed." There are ordinary wells and a number of deep wells which are from ninety to a hundred and sixty feet deep. There are some "mineral springs" reported, but I have no definite information as to them. One correspondent writes: "On the farm of W. B. Field is a spring which is flowing for six months and dry the other six months. This spring begins to flow when the first snow appears on the Green Mountains and dries up when the snow leaves the mountains. When running it would give a five-inch stream constantly."

GOSHEN. Mr. F. V. Hooker writes: "There is scarcely a place in Goshen that is not well supplied with good spring water from the neighboring hills."

GRANVILLE In this town the residents use springs far more commonly than anything else. The water is pure and soft. Wells, 10-15 feet deep are also in use though only to a very limited extent.

HANCOCK. Springs generally supply the needed water, which is good and soft.

LEICESTER. Ordinary wells are used mostly in this town.

LINCOLN. Though a mountain town, this place according to reports received uses wells more than springs, although springs are not at all uncommon. Mr. C. H. Heywood reports six never failing springs on his farm, some of which supply several families. This is in West Lincoln.

MIDDLEBURY. Formerly this town took its water from Otter Creek with the result that typhoid became altogether too frequent. A few years ago a new system was installed. The water is taken from springs in Bristol notch, 700 feet above the town and piped seven miles to a reservoir on a hill above the village from which it flows by gravity. See table for analysis. Outside of the village springs are much used. In East Middlebury wells are used.

MONKTON. In this town wells and springs are used about equally. Most of the wells are ordinary dug wells, but there are a few bored wells, one of which is 300 feet deep. Another well, drilled by M. O. Snow & Co. for Miss Eliza Brown is 200 feet deep. The water is 114 feet deep. The well goes through 188 feet of soil and 18 feet of rock. The water is soft and 3,000 gallons daily can be obtained by pumping. A windmill is used.

NEW HAVEN. Wells and springs are both used and in about equal numbers in this town.

ORWELL. Wells and springs are most commonly used and apparently in about equal numbers, but in that part of the town which is near the Lake water is pumped from it by windmills. Cisterns are also used to some extent. The wells are from 12 to 20 feet deep.

PANTON. Mr. R. J. Kent, writes: "A large portion of the water in my immediate vicinity is taken from Lake Champlain. Springs furnishing large water supplies are not found in this locality."

RIPTON. This is a mountain town and all needed water can be obtained from springs and brooks.

SALISBURY. Wells and springs are used, but wells mostly.

SHOREHAM. Wells are mostly used in this town, but they are deeper than in most parts of the State. Drilled wells from 50-100 feet are not uncommon. There are also springs. The water is all of it, hard.

STARKSBORO. There are both springs and wells in this town, and both are used for domestic supply. Mr. L. G. Ferguson writes: "The largest spring in town is situated about half a mile east of the village. It furnishes most of the water to run a sawmill which is about a hundred rods below it."

VERGENNES. This town has a public supply taken directly and without filtering, from Otter Creek. The character of this water is very unsatisfactory and steps are being taken to change the source of supply.

WALTHAM. Supplied mainly by springs, though there are some wells.

WEYBRIDGE. Supplied mostly by springs, though there are a few wells in use.

WHITING. This town is mainly supplied by water from drilled wells which are moderately deep. The water is hard.

BENNINGTON COUNTY.

This County forms the southwestern corner of the State. It is thirty-nine miles from north to south and twenty from east to west at the north end which is widest. The area is about six hundred and ten square miles. A portion of the great marble area of western Vermont extends south from Rutland county through Wallingford, Dorset to Manchester. The surface of much of this county is very irregular and there are numerous low mountains, that is over two thousand feet, but not much beyond this, culminating in Equinox at Manchester, which is 3,816 feet in height. Often the heights are near each other, giving rise to numerous deep, narrow stream valleys. The streams are numerous, but there are few ponds. The rocks are largely crystalline and precambrian, but some are later.

The county contains seventeen towns.

ARLINGTON. This town has a public water supply which is taken from a large spring on Red Mountain. This source is about a mile and a quarter from Arlington and 200 feet above it. "Every family, except two or three which use wells, receives its supply from this system. The water is sent to the State Laboratory every three months for analysis. It is somewhat hard, (about 80) but is used for laundry purposes. Red Mountain spring boils up from a mass of rock, is walled up for ten feet and covered. The nearest dwelling is eighty rods distant. There is a reservoir holding thirty thousand gallons. Before this water was used, wells varying in depth from 20 to 45 feet furnished most of the water used."

C. A. TOWLE, *Pres. Arlington Water Co.*

EAST ARLINGTON. This part of the town is mainly supplied by springs, but there are some wells, both dug and driven.

BENNINGTON. "The Bennington Water Company use mountain springs from which water is brought to the village by gravity." Attempts have been made in this town to get water by artesian wells. Two were drilled by Mr. H. W. Putnam, one one thousand two hundred and twenty-five feet deep, the other two hundred feet, but no water was reached by either. There is a large storage reservoir holding 75,000,000 gallons and a distributing reservoir holding 1,000,000 gallons. The pressure in the village is 125 pounds.

Some fine springs are reported in North Bennington.

Mr. W. G. Shaw writes of this part of the town: "The substratum of this vicinity is lime rock. There is also a fault. On the west side of this fault a stream of pure, hard water is found at a depth of fifty or sixty feet. On the east side nothing of the sort is found." Of Bennington Center, Mr. E. S. Chandler writes: "Water in the immediate vicinity is hard in both wells and springs, but the supply for the water system which comes from the Green Mountains is soft. Outside of the village limits there are numerous small springs. There are no wells in the village, all are supplied with running water."

DORSET. Mr. E. H. West writes: "Water in Dorset is mostly from springs, but both dug and driven wells are used. Dug wells are from fifteen to twenty-five feet deep, driven wells from twenty-five to forty-five. There are no very large springs, but a large number of comparatively small ones on the west side of town in that part known as Dorset Hollow. Anyone of several of these would furnish a splendid supply for Dorset. In the extreme east part of the township there are a few fairly large springs of good water which would furnish a constant supply for both East and West Dorset. In one driven well the following material was penetrated: Loam, 5 feet; gravel, 20 feet; putty clay, 8 feet; sand, 2 feet; hardpan, 8 feet, and water was reached. The character of the material gone through varies greatly. In a well within twenty-five rods of the one just mentioned they went through 116 feet of quicksand without striking hardpan."

GLASTONBURY. The supply in this town is mostly from springs though a few wells are used.

LANDGROVE. Wells and springs furnish water for the people of this town. Springs are used more than wells.

MANCHESTER. Mr. D. K. Simonds writes: "All our villages are supplied by a fine water system from springs at high elevation on the mountains east and west of us and almost all the farms outside are supplied with running water from the foot hills lower down. This water is good, but contains more or less lime carbonate. The springs from which the water system gets its supply are above the lime and the water is soft."

The famous Equinox spring is often supposed to be a mineral spring, but it can hardly be so considered as its mineral content is very small as the analysis given below shows. Its value consists in its purity rather than in any mineral which it holds in solution. An analysis made by Prof. C. F. Chandler in 1892 is as follows:

One U. S. Gallon, 231 cubic inches, contains:

Bicarbonate of Soda	0.5512	grains
Chloride of Sodium	0.4783	"
Sulphate of Potassa	0.0772	"
" " Lime	0.1484	"
Bicarbonate of Lime	1.9787	"
" of Magnesia	0.7338	"
Oxide of Iron and Alumina	0.0139	"
Silica	0.1796	"
Organic and Volatile Matter	Traces	
Total Solids	4.1611	grains
Total Residue on Evaporating at 240° F.	2.8888	"

The spring is on the side of Mt. Equinox 1,200 feet above the village. Its temperature is usually 398 F. The water issues from the schistose rock of the mountain. The water is piped to a small covered basin near the spring and then it runs to open reservoirs built of cement and stone which have a combined capacity of 350,000 gallons. Most of the village supply comes from this source, but there is another basin on the east of the town on the Green Mountains and from this water can be taken in case of need.

MANCHESTER CENTER. This village has an independent water supply. The water is taken from springs in the hills.

PERU. This is a very hilly town and the whole region is abundantly supplied with springs which furnish ample water for all the needs of the residents.

POWNAL. Wells and small springs supply all needed water. It is mostly hard.

POWNAL NORTH. There is in this village a public supply built by the Pownal Manufacturing Company. The water is taken from springs which form a small brook. A dam built across this brook forms the reservoir from which the water is taken to numerous families and the mill.

READSBORO. Springs supply the entire village. The system is owned by the village and the water from springs flows into an open reservoir which was enlarged in 1903 to cover eight acres. The intake is three hundred feet above the village.

RUPERT. Wells are mostly used in this village, though a few springs are used. In North Rupert mountain springs are mostly used for domestic water supply. There are also some driven wells.

SANDGATE. Both wells and springs are found on the farms of this town. The wells are from 12-45 feet deep. The water is hard in some, soft in others. Some families use water from streams.

Mr. Reuben Bentley, writes : "The town is as a whole very well watered. Streams run from hillsides and valley, there are many cold springs. One in the south part of town flows from a rock and has been in use many years. It is very cold, but hard water. Near this Parker spring, are two belonging to me that never fail, and make streams. One is soft water. There are many others."

SEARSBURG. Water mostly from springs. Mr. George Farrington writes: "We have no deep wells in town and our water supply is almost wholly from springs from the mountain side and the water is soft and pure. The springs are from three to five feet deep and are stoned up. I know of only four wells in town and they are not used for drinking purposes. In one the water is colored, and, I think, charged with iron."

SHAFTSBURY. Wells and springs used. Most of the wells are shallow, but some are deep. One is sixty feet. There are several large flowing springs. One of these is owned by the Eagle Square Company and is used by several families as well as in the boilers of the mill. Another, owned by A. O. Huntington, supplies several families and "There is enough running away to supply a good-sized village." The uniform temperature of this spring is 48 F. Smaller springs are common. Where these are not available water can be found by digging 15 to 20 feet.

STAMFORD. "Nearly all the people in this town get their water supply from the numerous springs found in nearly all parts of the town. There are a few ordinary wells. The water is all soft and of good quality."

M. L. WHITNEY.

SUNDERLAND. Only spring water is used in this town.

WINHALL. Most of the water used for domestic purposes comes from springs. There are some small wells, none over 8-10 feet deep from which water is pumped. All spring and well water is soft."

C. B. WILLIAMS.

WOODFORD. "Most of the water supply comes from springs boiling up from the ground. There are perhaps a dozen wells from 8-30 feet deep. One of the wells is hard and it is the only hard water in town."

D. W. GLEASON.

CALEDONIA COUNTY.

This county is bordered on its entire eastern edge by the Connecticut and the Winooski and Lamoille rise within its limits while the Passumpsic, formed by the union of two branches at West Burke, flows southward from that point to enter the Connecticut at Barnet, thus it flows for some twenty miles of its course through the county.

Much of the surface of the county is hilly and irregular, but except in the western part it is not mountainous. Ponds are numerous and a few are of considerable size.

As would be expected, the reports of different towns show that in the hilly portions springs abound, while through the more level eastern part wells are common.

There are seventeen townships in the county.

BARNET. Although this town is in the eastern part of the county, it is mainly furnished with water from springs though there are some wells.

There are several public supplies. One, owned by Mr. G. I Brown, furnishes water to about thirty families. The East Barnet Water Company supplies a considerable number of households.

Mr. Brown reports that the springs owned by him have not failed even in the driest time for a hundred years.

It is said that in EAST BARNET there are no wells at all, all the water used coming from springs.

Mr. C. T. Kendall of the East Barnet Water Co., writes: "The East Barnet Water Company has been in existence a year and a half (1903). We have in a two-inch galvanized pipe and all the water we use comes from one spring about which we have made a reservoir holding about two hundred and fifty gallons. There are other springs piped to houses. All the water used here comes from springs."

In WEST BARNET, however, while there are many springs, there are also many wells.

In the village of MCINDOES FALLS, which is in this township, springs are especially abundant. Mr. F. H. Colby writes: "I do not think that there is a farm in town that has not a lot of water to spare. I am interested in three lines of water supply. One has eight families and each of the others twelve. There are several other supplies here that have about the same number of customers. The water runs all the time and is pure and good." Mr. W. H. Gilchrist, of the same village writes: "We have no very large springs in this town. Most of the water comes from springs on the hillsides which supply from one to twenty families."

BURKE In this town there are several supplies, one owned by the town and two or three small systems owned privately. Ordinary wells supply a portion of the town. These wells are from 25-30 feet deep and some go down into the rock. The water is hard .

DANVILLE. There are here very few wells, the water nearly all of it coming from springs. Mr. J. H. Stevenson says: "Nearly every landholder in this section gets water from springs. A few dig wells from 6-29 feet deep. The same is true of South Danville."

GROTON. The water used in this town comes mainly from springs. Mr. F. W. Page writes: "Nearly everyone has a good spring which never fails from which he obtains his water supply. A few use ordinary wells, but most use springs."

HARDWICK. Springs abound here and no wells are reported. The town supply is taken from Eaton brook about three-fourths of a mile from the village, but the supply is not sufficient for emergencies. The brook is fed by springs. There is an open reservoir holding 200,000 gallons.

KIRBY.—The water here is reported as "abundant and good." It is mostly from springs, but there are some wells in use.

LYNDON. . There is here a village water system and several less public supplies from each of which several families take water. There are several quite large springs in the town. The village is supplied with water from reservoirs into which springs flow.

LYNDONVILLE. This part of the town of Lyndon has its own public supply. The water is taken "from a brook which rises in a cedar swamp." There is an open reservoir high enough above the village to give a pressure of 145 pounds. There is also another system owned by the Lyndonville Water Co. which takes its supply from a brook fed by springs. The Boston & Maine R. R. has a third system which takes the water of certain hill-side springs to a reservoir from which it is distributed.

The water from all three of these sources is hard, but appears to be otherwise good.

NEWARK. Springs are mainly used here for family supply, but there are also ordinary wells. A mineral spring is reported the water being sulphurous.

PEACHAM. Wells and springs are both reported as in use in this town, but springs are most used.

RYEGATE.—"Nearly every house in town has water piped from some spring."

SHEFFIELD. No wells are reported in use in this town. Springs furnishing all needed water.

ST. JOHNSBURY. There are few or no wells used in this place. The supply is from two systems. One owned by the village takes water from the Passumpsic river, pumping it directly into the mains. This river system is used less and less for domestic purposes as the water is unfit for such use. The pumps are worked by water power usually, but there is auxilliary steam power for use in time of need. In the early part of 1904 this water was said to be used by about a fourth of the people but this number is constantly decreasing.

The other system takes water from a pond in Waterford, hence it is called the Waterford System. This pond has an area of some seventy-five acres or more, is four miles from St. Johnsbury and 360 feet above, the lower part of the village. The pond is fed by springs and the water is run through large sand filters before it is distributed. There are three of these filters each fifty feet in diameter and forty-two inches deep. "The water shed is large, wooded, and sparsely settled."

STANNARD. Wells and springs are both used, the latter mostly.

SUTTON. "Our water supply is from flowing springs or a few ordinary wells."

F. A. HOLMES.

F. A. Pillsbury & Son report a very fine large spring which they own, located in this town. The water is pure, cold, and abundant.

WALDEN. Mr. C. H. Stevens writes: "There are no wells in this vicinity. The people are supplied with water from springs on their own land."

WATERFORD. Some wells are reported from this town, yet Mr. E. Bowman reports: "This is a farming community with abundance of living springs. Everybody has running water. I do not know of a person in town who has to resort to artificial means to get water except to lay a pipe to bring it to the house."

Mr. A. B. Carpenter corroborates the above as follows: "There is a mountain range running northeast and southwest through the town and on the west of this many springs gush out. In a distance of a mile and a half fifteen large springs may be found, besides many small ones."

As noted previously, Stiles pond from which water is taken by St. Johnsbury is located in this town.

WHEELOCK. This town is well supplied with springs.

CHITTENDEN COUNTY.

Chittenden county forms a part of the east shore of Lake Champlain. It is for the most part uneven, indeed this may be said of most of this State. It is not, however, as rugged as are many parts of Vermont, and contains considerable fairly level ground.

It is thirty miles from north to south and twenty-two from east to west. Its area is not far from five hundred and twenty square miles. In the western part of the county near the lake the rocks are nearly all stratified, shales, limestones, sandstone. The headlands which here and there extend into the lake as promontories are mostly of the red sandstone which is middle Cambrian. Some, as, Colchester point are Utica Shale, and a few as McNeils point are Ordovician limestone. The Cambrian and Ordovician rocks are limited to a rather narrow area near the lake while a few miles east the rocks are all metamorphic, schists, gneiss, etc.

North and east of Burlington there are extensive sand plains. Probably the greater number of the residents of this county get water for domestic purposes either from the lake or from wells and, as a whole, the region is not so well furnished with springs as is much of the State.

The main streams are the Winooski, which flows through the country from east to west, the Lamoille, which flows through the northern part and numerous smaller streams. Ponds are not numerous.

There are sixteen towns in the county.

BOLTON. This town is located at the base of Camels Hump and in part on the slopes of that mountain, and like all of our mountain towns, it is well supplied with springs. As to this Mr. G. A. Pease writes: "The town is supplied with an endless number of small springs of purest water issuing mostly from rocks. I presume that within a circle of a mile almost anywhere in town probably a hundred springs could be located." The water is reported as very soft.

BURLINGTON. The needs of this city are mainly supplied by the public system which, as will be seen in what follows, takes water from Lake Champlain, pumps it by steam to two large reservoirs on the "Hill" whence it is distributed by gravity to all parts of the town. These reservoirs have a capacity of 7,000,000 of gallons and there is an iron reservoir holding about 170,000 gallons from which a smaller number of families living too near the level of the large reservoirs to take water from them are supplied.

In the business part of the town the pressure is 80 pounds. There has for some years been more or less complaint by residents on the shore of Lake Champlain that the water of the lake was greatly injured by the discharge of waste from pulp mills on the New York shore and by towns on the shore, especially Burlington.

The agitation of the question whether the water was really polluted by these discharges or not led to a request from Governor McCullough to the Director of the U. S. Geological Survey that he assign a competent investigator to examine the water of the lake and make report thereon. Accordingly, in 1903, the director assigned Mr. M. O. Leighton, of the Survey Staff, to this duty. Investigations were made during the summer of 1903 and a report published by the Survey in 1905.

The entire report, which is published as Bulletin 121, Water Supply and Irrigation Papers, is interesting and instructive, but only those portions which refer directly to Vermont can be given here. These I have thought it best to give plainly in the author's own words. Although the report does not claim to be complete, but only "preliminary,"it is by far the most careful and thorough investigation of the water of Lake Champlain from a sanitary point of view that has yet been made.

In this connection a brief review of the history of the water supply of Burlington will be interesting. The following is compiled from various sources. Prior to 1867 most of the families living in Burlington had wells from which they obtained all the water they used for domestic purposes except that in some cases cistern water was used for washing. There were also a few springs, some of them quite strongly impregnated with mineral substances. In 1867 a public supply was established, the water being pumped from the lake to a reservoir on the "Hill." The intake was located not far from shore near the north end of the docks. For a time this water was considered pure and wholesome. In a few years, however, many persons began to feel ill effects from the water, or at least they supposed that the water was injuring them. During the following ten years intestinal troubles increased and the suspicions that the water was affected by the sewage of the city, the outlet of which was not far south of the intake, grew stronger. Still all sickness that could with any show of reason be traced to the water was of a comparatively mild sort. There were cases of typhoid fever in town, but not in any larger number than in towns having a water supply of established purity. Little was done until 1888 when an investigation was carried on for some weeks and numerous analysis of the lake water were made by several chemists. The results of this investigation do not appear to have been very conclusive, but so far as they showed anything of importance they showed that the water used was not found to be so impure as to afford good ground for anxiety.

Notwithstanding this report, which was published in the twenty-fifth annual report of the city, more or less uneasiness prevailed among the citizens and this increased in the years immediately following and finally reached such importance that Prof. W. T. Sedgewick, of Boston, was called upon to make a special examination of the water supply of the city and to report upon it. A portion of Professor Sedgewick's report is given in the following quotation:

"I am informed that many of the physicians regard the water supply with suspicion, and I find that the successive health officers in their official reports have frequently referred to the water as more or less objectionable. I therefore undertook, first, to discover the actual effects of the water supply upon the health of the city.

"In order to do this in the case of a water supply suspected of sewage contamination it is customary to take as a measure the prevalence of diarrheal diseases and especially typhoid fever. I have therefore carefully studied the vital statistics of Burlington for the last twelve years, comparing the mortality from typhoid fever with the total mortality and also with the number of inhabitants.

"The results show conclusively that the mortality from typhoid fever (and the same is true for diarrhea and dysentery) has not been large in Burlington during the last twelve years. The average annual mortality from typhoid fever from 1870 to 1891 in Burlington was 3.57 per 10,000 inhabitants.

"I then went on to show that Burlington compared favorably in this respect with many cities having water supplies of undoubted purity, and stated that in respect to mortality from typhoid fever it had a better record than 'many cities having water supplies of good reputation.' This weighty fact alone justifies the conclusion that there is no positive evidence in the sanitary statistics of the city that the water supply is injurious to public health. I may add by way of confirmation that during the last three years I have made repeatedly bacteriological analysis of the Burlington supply, and that I have found no satisfactory evidence of the presence of sewage in the drinking water.

"In fine, I am of the opinion that there is no positive evidence of any injurious characteristics in the present supply. But I believe nevertheless that in view of the common occurrence of diarrheal disturbances reported by physicians, and on account of the menace to the public health involved in the present arrangement, some other source of supply should be found. I think that it would be of very great sanitary advantage to remove the intake as far as possible out into the broad lake."

As a result of this recommendation after some consideration the city decided to extend the intake out to Appletree Reef, a distance of three miles. This was done in the summer of 1894. After this extension was completed and the supply taken from the new station, the intestinal and other troubles which had been more or less prevalent in the city, almost entirely ceased and analysis showed a marked improvement in the quality of the water. Since the improvement just cited was made the conditions in and around Burlington have materially changed and the present conditions may be given as follows, quoting from Mr. Leighton:

"Burlington, Vt., has, according to the Twelfth Census, a population of 18,640. It is situated on the east side of Lake Champlain, in the center of a broad bay, shown in fig. 4 (p. 77). The water supply of the city is pumped from the lake—the intake being situated northwest of the city at Appletree Shoal—through a suction pipe extending along the bottom of the lake to the pumping station on the lake front, nearly opposite the north end of the harbor breakwater. The sewage of the city is carried by a trunk sewer to the water front and emptied into the lake at the shore nearly due east of the south end of the breakwater. All sewage except a small, insignificant quantity is discharged through this outlet.

"Into the small bay defined by Lone Rock Point and Appletree Point are discharged the wastes of an extensive rendering establishment.

About two miles north of Appletree Point, Winooski River empties into the lake. This river drains 995 square miles in the State of Vermont, most of it farming or mountain land. Near the upper end of the river is situated the city of Montpelier, and near the mouth are Fort Ethan Allen, an extensive United States Army post, and the village of Winooski, containing 3,783 inhabitants. From both the army post and Winooski village are discharged large quantities of sewage.

The geographic relations of the various points above mentioned to the configuration of the shore are important, as they are such as to protect large areas of water and render them comparatively stagnant, that is, they are so situated that circulation must be considerably less than that in the broad lake. A few miles south of Burlington, Shelburne Bay, a large body of water from 70 to 100 feet in depth, makes into the mainland. Shut in from the rest of the lake except at the comparatively narrow outlet between Shelburne and Red Rock points, this bay is comparatively stagnant. A slight current from the north seems to flow along the shore above Red Rock and circulate in the bay. This is quite pronounced when a strong north or northwest wind is blowing. This bay is therefore considerably polluted by the sewage of Burlington, and on account of the lack of dilution the water reveals a somewhat higher amount of organic matter than has been noted in the water of the broad lake. Burlington is protected by a long, artificial breakwater around which the current swirls, the direction depending largely upon the direction of the prevailing winds. It has been noted by various observers that when the wind blows from the south the current seems to be deflected from the lake into the south end of Burlington Bay, thence northward inside the breakwater. Similarly during a northerly wind the subcurrent runs south behind the breakwater. Just north of Burlington there is a small area of comparatively dead water eastward from Lone Rock Point.

Between Lone Rock Point and Appletree Point there is another bay well protected except from southerly winds. This is the bay into which the offal from the rendering establishment is turned, and at the mouth of which, on Appletree Shoal, the water intake of the city has been placed. North of this, Winooski River makes out into the lake at a southerly angle, the current deflecting southward even when the lake surface is quiet. Now, as has been stated on previous pages, the normal current of the lake at the shore is southward. The water of Winooski River when discolored by floods is readily traceable southward into the lake, the track having been observed as far south as Juniper Island when strong northerly winds were prevalent."

EFFECT ON LAKE CHAMPLAIN.

The conditions above recited seem to be well adapted for confining the impurities coming from the Burlington sewers and from Winooski River in that immediate region, the trend of the impurities varying with the immediate local conditions. Normally, without winds, the sewage from Burlington takes a southerly turn along the shore of the lake and swings outward, taking a northerly course by Appletree Point, or a little farther to the west. The water of Winooski River apparently flows south and then swirls into the broad lake in the same manner; thus the impurities are concentrated first at one place and then at another, the ultimate mixture giving to the water in the region of Burlington and for several miles north, south, and west a character which by no means warrants its consumption for domestic purposes in the raw state. The impurities issuing from Burlington and the Winooski are almost entirely of a sewage nature, there being very few industries the waste from which complicates the pollution problem in an important degree. The specific tests by which this pollution can be traced are the familiar ones commonly used in sewage-pollution cases. There should be under normal conditions a general increase in the amount of chlorides in the water, a slight rise of the amount of organic matter, but most of all a surplus of intestinal bacteria, of which the *Bacillus coli communis* is the most familiar.

It was necessary to secure some data concerning the normal water of the lake, or rather to secure as good an idea as possible of what the lake water would be if it were well mixed and the various ingredients uniform in proportion. For this purpose samples were collected in those portions of the broad lake which seemed to be least affected by polluting influences, whether natural or artificial.

Inorganic and sanitary analyses of water from Lake Champlain.

SAMPLING POINT.	SiO_2	$Fe_2O_3+Al_2O_3$	CaO.	MgO.	Na_2O.	Cl.	SO_3	CO_2	O rep. by Cl.	Total solids.	Alk.
Gull Island Reef	4.8	1.8	19.19	4.72	8.2	1.1	6.0	22.66	0.479	67.973	47
2 miles north of Four Brother Islands	3.2	.8	19.19	4.72	8.89	1.2	5.8	22.58	.542	65.838	46
Mouth of Willsboro Bay	3.4	.8	22.20	5.13	7.41	1.2	7.1	23.63	.542	70.329	47
New York shore, Chesterfield Township	4.4	1.0	20.01	4.63	8.35	1.4	5.5	22.83	.63	67.49	47
½ mile east of Four Brother Islands	3.0	1.0	19.42	4.45	7.14	1.1	6.6	20.60	.497	62.81	47
Average	3.76	1.08	20.00	4.73	8.2	1.2	6.2	22.46	.542	66.89	47

SAMPLING POINT.	Total solids.	Loss on ignition.	Per cent. of loss to total.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Hardness	B. coli-com.
1½ miles north of Split Rock	67.0	20.0	30.0	0.130	0.042	0.002	0.100	1.0	51.4	None.
2 miles south of Quaker Smith	72.5	26.0	36.6	.132	.038	.002	.080	1.0	50.0	None.
1½ miles east of Jones Point	63.2	21.0	32.8	.120	.028	.002	.090	.8	50.0	None.
1 mile south of Juniper Island	65.0	22.0	33.8	.156	.032	.002	.100	.8	51.4	None.
1 mile west of Four Brother Islands	60.2	20.0	30.9	.122	.014	.001	.090	.9	50.0	None.
Average	65.6	21.8	32.8	.132	.031	.002	.092	.9	50.6	None.

It will be noted at the outset that the water contains a fairly high proportion of dissolved solids for this part of the country. Where in this case the water contained from 63 to 70 parts per million of total solids, Lake Winnepesaukee in New Hampshire contains 20 parts; Rangeley Lakes, in Maine, 20 to 26 parts; Moosehead Lake, in the same State, 23 to 24 parts; while the various smaller lakes and reservoirs in Massachusetts contain from 18 to 37 parts of dissolved matter per million.

The analysis given in the table further show that the quantities of lime and magnesia found in the water are extremely high for this part of the country, the lime running from 19 to 22 parts per million, while that in the water of Rangeley and Moosehead lakes is approximately from 2.2 to 2.5 parts. The amounts of iron, aluminum, and silica are fairly large, while the proportion of soda is far higher than in any other surface water of New England. It is essentially a carbonate water, although the amount of sulphate contained in it is proportionately somewhat greater than is usually found in this part of the United States. The chlorides are high, exceeding by about 100 per cent the normal chlorides for this region.

The sanitary analysis shows that the water contains a small amount of organic matter. The fact that the amount of chlorine is above the normal for this section is unmistakable evidence that the water has been polluted. Indeed, it is not necessary to refer to an analysis to determine this point. But the amount of organic matter in the samples under investigation certainly indicates that the water in the broad lake is of satisfactory quality. The amount of albuminoid and free ammonia is considerably less than that contained in several normal surface waters of New England, while the nitrites and natrates gives insignificant testimony, save that in the case of the latter it is shown that oxidation has been rapid and abundant. No bacteria of intestinal origin were found in this water. As might be expected from the large amount of calcium and magnesium noted in the inorganic analysis discussed above, the water is very much harder than that generally found throughout New England, the hardness determined by the soap method being, on the average, 50 parts per million, against 2 to 12 parts in the lakes and reservoirs of New Hampshire, Massachusetts, and Maine.

After quoting much more fully from the report made in 1892 by Professor Sedgwick than has been done in this article, Mr. Leighton comments as follows:

"The statements above recited with reference to the water supply of Burlington indicate in a measure the condition of the lake in front of the city twelve years previous to the investigation of which this publication is a report. Since that time the population of Burlington has increased about 30 per cent. Therefore, the conditions, admittedly bad during that period, must of necessity be still more unfavorable at the present time. It is therefore safe to enter upon the investigation with the assumption that Burlington sewage does damage the lake, and the problem resolves itself into a question of the extent of that damage.

One of the most striking features in connection with Burlington pollution brought out by the report of Professor Sedgwick is the apparently enormous power possessed by the lake to assimilate large quantities of contaminating matter and to conceal almost every chemical as well as biological evidence of the presence of pollution. It is inevitable that the increased quantity of sewage resulting from the increase in population above stated will render the detection thereof in the lake a less difficult matter than during the period covered by Professor Sedgwick's report. In addition to this, the interesting question presents itself, whether or not by the continued pollution, year after year, the lake immediately surrounding has lost a part of the remarkable power which it was at that time shown to possess of assimilating these impurities and making their detection difficult. Undoubtedly precipitation of the organic matter is a great feature of this so-called assimilating power, and it has been well shown that the continued sedimentation of putrescible matter will in time result in such large accumulations that the actual conditions will assume those somewhat similar to a septic tank. In other words, the area will become a seat of fermentative changes, the result being that the character of the surrounding water reveals these conditions and a large part of the power to conceal sewage is lost. No opportunity was afforded to investigate with reference to this particular point, but the results hereinafter submitted contain interesting suggestions with reference to it."

In Mr. Leighton's report a table follows the above, giving analysis of a series of samples of water taken at different stations along the shore south of Burlington and around Shelburne Bay. Concerning these the author says:

"Although the results set forth in the above table indicate unmistakably the polluted condition of the water in the region in which the samples were taken, there appears to be no continuity nor general logical trend as the distance from the polluting point is increased or diminished. The results also emphasize the fact that although a large amount of sewage matter is turned into the lake at Burlington the determination of volatile solids does not set forth the conditions clearly. This determination is, therefore, unworthy of confidence except in those cases where the accompanying determinations agree relatively with them. A few of the samples, such as Nos. 10, 12, 13, and 16, show a percentage of volatile solids considerably higher than the normal for the lake, and it will be noted that the chlorine in those samples is abnormally high. On the other hand, the results of the determination in sample 6 show a normal amount of volatile solids with extraordinarily high chlorine. As might be expected, the chlorine determinations give the specific results valuable in the investigation. It will be seen that by far the greater majority of the samples contained an amount of chlorine considerably higher than the normal. This can be due to nothing else than the Burlington sewage. On the other hand, there were several samples containing a normal amount of chlorine, which may be explained by the statement that the dilution by the purer water from the broad lake must be irregular in the bay, as in fact the physical conditions would indicate. The results of analysis of several series of samples of water taken at stations north and south of the city are then given and finally, the following

CONCLUSIONS:

The data show clearly that the sewage of Burlington and from Winooski River pollutes practically the entire shore from Colchester Point to Shelburne Bay and includes within the contaminated area the water intake of the Burlington city supply. How much more extensive the effect of pollution from these two points may be, opportunity was not afforded to determine. The area included within the investigation is sufficiently large to indicate the general pollution of the water in this vicinity. In connection with the report on the early conditions of the Burlington water supply mentioned on pages 68-74, it was shown that evidence concerning the persistence of sewage matter in the lake is particularly elusive and that the best methods of identifying the unfavorable effects of Burlington sewage disposal was found to be in the improvement which was shown in the occurrence of intestinal diseases in the city. There has been no general inquiry with reference to the abnormal amount of so-called diarrhea in Burlington since the investigation made by Professor Sedgwick. Nevertheless, the typhoid records in that city are not such as to inspire confidence in the water supply. A report of the local board of health shows the following typhoid records:

Typhoid cases in Burlington, Vt., 1900—1904.

YEAR.	Cases reported	Deaths.
1900	....	7
1901	22	3
1902	19	3
1903	29	2
1904[a]	31	....

[a]To November 25.

The record of deaths from typhoid in the year 1904, up to November 25, was not available, and the report of the number of cases is probably not correct. Local officials state that many of the typhoid cases which have occurred during the year 1904 are not yet reported to the health officer, and that when the final returns are made the number stated above will be increased materially. Compared with the earlier conditions stated in the report of Professor Sedgwick, the present death rate from typhoid appears to be no greater, but, although the earlier morbidity statistics are not available, it is generally admitted by those conversant with the typhoid history of Burlington that the disease is more prevalent than formerly. Dr. B. H. Stone, director of the laboratory of hygiene at Burlington, has reported that 33 per cent of the daily samples of Burlington water taken from the laboratory tap during the month of November showed the presence of *Bacillus coli communis*. For each of these determinations only 1 cubic centimeter of the water was subject to examination.

Considering the results of the sample series stated in previous pages, the degree of prevalence of typhoid fever in Burlington, and the results of examinations made at the State laboratory, it appears to be unquestionable that the sewage of Burlington and Winooski River is highly damaging to the lake in that vicinity. The area in which *Bacillus coli communis* was identified is much larger than any comprised in any other investigations where specific examination was made for evidences of pollution. Burlington is undoubtedly the source of the most serious contamination occurring in the lake."

The following from this report on algae in the water of the lake will be of interest to many who have noticed and wondered at the abundant growth of plants of this sort during the latter part of summer.

"The statement has repeatedly been made that, as a result of the discharge of foreign material into Lake Champlain, there is a super-abundance of algae of the offensive species. In fact, this has been considered one of the main points of evidence in support of the charge that the lake is being damaged by municipal and industrial wastes. Therefore it was believed necessary to give as much attention as possible to this phase of the question. It was impossible to undertake the refined series of experiments necessary for a final opinion on this point, but sufficient observations were made to permit certain generalizations.

Nearly all quiescent surface waters contain microscopic organisms in large numbers. The occurrence of these organisms in such waters is as natural as the occurrence of fish. They take their place in the flora and fauna of water life as inevitably as do the water lily, the tadpole, the eel, or the brook trout. The mere presence of algae in a water is certainly not evidence of any unnatural feature. On the contrary, their absence would be unique. Therefore the supposition that because of a superabundant growth of algae along the shores of a lake there must be polluting material turned into the water is unfounded.

There are many varieties of algae. A sample of water from almost any lake will reveal numerous kinds. Nevertheless, they have a seasonal distribution. For example, a certain species may be found in abundance in spring and in only small numbers in summer or autumn; likewise, a different species may be scarce or absent in spring but especially numerous in summer or fall. Similarly, a certain kind of algae may be abundant during one year, but scarce during the next year or a cycle of years thereafter. These variations may be due to causes quite as natural as those which bring about similar fluctuations in the potato, corn, wheat, or cotton crops. The fact that a certain troublesome algae appears along the shores of a lake during several seasons in greater abundance than in former years can by no means be attributed offhand to any change artificially made in the character of the water.

Some organisms thrive under certain conditions of water: therefore the presence of such organisms in exceptional numbers may be taken as an indication of those conditions. On the other hand, the absence of these forms may in many cases be interpreted as an evidence of the nonexistence of those conditions.

Algae die out unless food material is present, and increase in number as the food is increased. Organic matter, by its oxidization, supplies carbon dioxide and nitrates, which are favorite food for algae. Therefore, other things being equal, anything which would increase or decrease these products would have a consequential effect upon the number of algae.

Algae impart certain appearances, odors, and tastes to the water. Some of these features are the result of life processes of the organisms, while others are due to the products of their death and decay. These odors and tastes have no relation to any polluting material that might be placed in the water, but occur everywhere that the organisms flourish, whether it be in the high mountain lake with no suspicion of artificial contamination, or in a stagnant pond which receives city sewage."

A large portion of Mr. Leighton's report is given to a consideration of the effect of the wastes from pulp mills and his conclusions as to these as well as the other matters involved in his study of the water of Lake Champlain are as follows:

"1. Soda-pulp waste from the Champlain mills of the New York and Pennsylvania Company, situated at Willsboro, N. Y., is not perceptible in Lake Champlain beyond a maximum distance of 2,000 feet from the mouth of Bouquet River, provided that the sedimentation bed installed at Willsboro is used.

2. Sulphite-pulp waste from the mills of the J. & J. Rogers Company, situated at Ausable Forks, N. Y., is apparently perceptible in Lake Champlain for a considerable distance from the mouth of Ausable River.

3. The sewage of Burlington and Winooski River is a serious damage to that part of Lake Champlain immediately surrounding. The inhabitants of Burlington are 'drinking from their own cesspool.'

4. Soda waste from the mills of the Ticonderoga Pulp and Paper Company, situated at Ticonderoga, N. Y., causes a high proportion of chlorine to appear in the lake water. There is no real damage from this source.

5. The water of the broad lake is of good quality.

6. The sewage conditions as a whole are a growing menace, and if the lake is to be preserved as a water supply the entire

question should be studied from interstate and international standpoints and the necessary safeguards provided."

What is to be the future of Burlington's water supply is at present undecided. Since the above report was given there have been numerous deliberations, several committees have been appointed and have sought in vain for a satisfactory solution of the difficulties which the case presents. The most likely solution, if one may venture any opinion upon so involved a matter, appears to be the disposal of sewage in some way other than running it into the lake and by securing Lake Champlain from pollution obtain from its naturally very pure water an ample and wholly satisfactory supply. Meanwhile, the citizens of Burlingtion who are wise, thoroughly boil the water supplied and remain in as good health as at least the average people of similar towns the country over.

Calling wells over fifty feet in depth, deep wells there are in or near Burlington about twenty-five, some of them several hundreds of feet deep. In most of these the water is hard and in most of those drilled in the city west of Church street there is a large content of magnesia so that the water cannot be used for steam as it clogs the pipes.

For information concerning these and other deep wells in the State I am much indebted to Messrs. J. P. Hoadley, M. O. Snow and J. A. Willams, well drillers, all of whom have courteously and fully answered all enquiries. Almost all of the deep wells in this city go through the surface drift and enter the underlying rock, but there are some as at the Gas Company's yard, which do not enter the rock at all, though very deep. The underlying rock is in some cases Cambrian Red Sandrock, in others Utica Shale. As is shown elsewhere, some very deep wells have been drilled in the Utica without finding any water at all.

The drift is extremely variable in thickness even in localities not distant from each other, being ten times as thick in some wells as in others. It will be instructive to notice in some detail the character of the material passed through and other facts concerning some of our deepest wells. Other similar facts are given as different towns are taken up in other parts of this paper.

At the Van Ness House there is a well 365 feet deep. The top of this well is 180 feet above sea level or 80 above the lake. The water ordinarily rises to within 42 feet of the top. About 3,500 gallons are used daily for the various needs of the hotel. As a drinking water it is much liked and is thought to be beneficial in cases of acid stomach and indigestion, but it cannot be used in the heating plant for the reason just mentioned. In drilling this well, at first there were 85 feet of drift and then 180 feet of red sandstone such as comes to the surface in many places in this region. The water is raised by a deep well pump.

At the Champlain Manufacturing Company's mill there is a well 410 feet deep, the water rising to within 15 feet of the surface which is at that point 25 feet above the level of the Lake. The flow is abundant and so is lime and magnesia, which so fill the steam pipes that the water is not used. In this well the drill passed first through 10 feet of sand, then 202 feet of clay and hardpan, then 198 feet of red sandstone.

At the building of Wells and Richardson Company there is a well 430 feet deep in which the water rises to within about fifteen feet of the surface. This is 84 feet above the lake. This well yields about sixty gallons a minute for eight hours daily. The water is forced into a small reservoir at the surface by the Pohld air system and then pumped by a force pump to a tank above the roof. This well passes through 80 feet of drift then 250 feet of red sandrock then the drill apparently struck a cavity as it sank suddenly 18 inches and at this point the largest quantity of water was obtained, although the drill was sent down a hundred feet more in the sandrock, but to no advantage.

At the Venetian Blind Company's mill nearer the lake is a flowing well. The surface is here only 15 feet above the lake and water in sufficient quantity to supply all the needs of the company was found at a depth of 138 feet. When this point was reached the water rose 18 feet above the surface and gave pressure of 8 pounds. When the well was capped, the water could be piped all over the two-story mill and the pressure rose to 13 pounds. The drill first passed through 98 feet of drift and then 40 feet of red sandstone.

Yet nearer the lake shore is a well of the Gas Company. This well is 164 feet deep; it has a 6-inch tube and the water rises four feet above the surface which is only 8 feet above the lake. A constant flow of 20,000 gallons in twenty-four hours is given by this well and the temperature is constant, being 42 F. This well was first bored through 30 feet of peat, 40 feet of clay, and 194 feet of gravelly hardpan, and does not enter the rock.

During the past year the Gas Company have completed a second well not far from the first. This well is 194 feet deep and goes into the sand rock 24 feet. In this the tube is 6 inches as in most of the deep wells, though in some the bore is 8 inches in diameter. In drilling this well there were found, first 65 feet of peat and then clay, then 105 feet of sand and gravel and finally, 24 feet of sandrock. This is also one of the few flowing wells in this region or for that matter, in the State. The water rises 16 feet above the mouth of the well, which is said to be only 8-10 feet above the lake. Water flows 45,000 gallons a day and has a uniform temperature of 45. Unlike most of our deep wells this gives water that is not very hard. In the same neighborhood, at the Whiting Brush Fiber factory, a well has recently been drilled. This is 218 feet deep, 65 through drift, the rest through rock. It is also moderately soft and also flowed 3-4 feet above the surface. It flows about 6,000 gallons a day.

About a mile north of the main part of town, on North avenue, is a well 150 feet deep on the property of Mrs. A. B. Kingsland. This water is reported very hard. Mr. Kingsland writes: "In drilling this well they went through 20 or 25 feet of soil, then 25 feet of red sandstone then through a layer of sand, and then sandrock again. The drillers said that they never before had the experience of finding sand between two strata of rock." Still farther north on the Barker place is a well 306 feet deep. In drilling this well several streams of water were found as the boring went down, but none large enough till the drill was down below 300 feet. Even then the flow was small and has remained so, only three to five gallons a minute, but sufficient for watering stock which is the purpose of the well. In drilling this well, there were first found a few feet of soil then 108 feet of quicksand, then 20 feet of reddish clay, then 168 feet of Utica Shale. The water is hard.

Still farther north and much nearer the shore of the lake, at the Burlington Rendering Plant, there was bored a well 490 feet deep, but no water was found. This well passed through 20 feet of sand then 100 feet of clay and then 370 feet of shale

In most places where wells have been drilled in the Utica shale either no water or only a small flow has been obtained, though there are some notable exceptions to this.

From the facts just given it is evident that the water in the deep wells although many of them are near the shore of Lake Champlain, does not come from that source. The elevation forbids this and the character of the water also is quite different from that in the lake.

In the region of Burlington, the land rises rapidly to the eastward from the lake to a height on "The Hill" of from three to five hundred feet. The surface of most of this elevation is covered with drift or beach formation, the latter on the slope towards the lake. From Dorset street the ground falls for some distance and on for eight or more miles towards the Green Mountains it does not reach the height of the top of the "Hill" ridge. All through this most elevated portion the underlying rock is the common red sandstone, Middle Cambrian, of western Vermont, and there can be no doubt that the water in most, though certainly not all, of the deep wells around Burlington comes through this rock.

It may be noticed that although hard, the water of these wells is very clear and is found beneficial by some dyspeptics who have taken to drinking it.

CHARLOTTE. There are many springs in different parts of this town, but on many farms it has been found better to drill deep wells as a more abundant and sure source of supply. Ordinary shallow wells are also common. I have data of some twenty deep wells in this town. Some of these are as follows: There is a deep well at Mr. L. McNeils'. This is 250 feet in depth, all but 60 feet in rock. It furnishes good, soft water at the rate of 2 gallons a minute. Mr. R. G. Whalley has a well 235 feet deep, 194 of which is in rock. It furnishes soft water, 5 gallons per minute. Mr. H. J. Carpenter has a well 180 feet deep. Of this 96 feet are in drift with much blue clay. The rest is in limestone. This well was at first put down to 155 feet and later 25 feet were added and the quantity of water was thereby doubled, although not very large, less than 2 gallons a minute.

The deepest well in this region is one put down by Mr. Ezra Meech. This is 280 feet deep. In this the first 190 feet pass through the drift, the remaining 90 feet found only shale. Mr. William Brothers has a well the depth of which is 91 feet and all in gravel, no rock being found.

It is good soft water and flows 15 gallons per minute. There are several others from 75-200 feet deep.

COLCHESTER. This town includes very different physical conditions. In some parts the surface is level and sandy while elsewhere it is hilly and there is much clay. There are some springs in the latter part of the town, but water is mostly obtained from wells except in that part of the town which is included in the village of Winooski where there is a public supply.

Leaving out this village for the present, we find that the wells are many of them shallow, but that there are also some deep wells.

In the sandy portions of the town the shallow wells are quite liable to become dry during a prolonged drought.

The principal deep wells are as follows: At Fort Ethan Allen, a military reservation a mile square which is situated in Colchester, there are four deep wells. The water in none of them rises nearer the surface than a hundred feet. These wells are respectively 375, 310, 320 and 420 feet deep.

Number one gives forty-two gallons a minute. Water is found in a layer of gravel. In well number two the water is found in limestone. This flows 52 gallons a minute. The beds passed through in these two wells are much the same. In number two they are—

Clear fine sand	20	feet.
Sand mixed with a little clay	85	"
Clayey quicksand	85	"
Clay mixed with sand	8	"
Quicksand	37	"
Blue clay	66	"
Boulders and gravel	10	"
White limestone	64	"
	310	

Number three passes through much the same beds. It flows 60 gallons a minute.

Number four goes down into a seam in the rcck from which 250 gallons a minute flow constantly. In this well beds of sand and gravel were gone through down to 400 feet, then a light colored limestone was reached and the last 96 feet were through this. The water is raised by compressed air, Pohld Air system. The water in these wells seems to be much the same. Several additional wells are now being drilled at the Post to supply the larger demand.

On the farm of Clark Rood which is more than a mile north west of the Post, there is a well 103 feet deep. In this the water rises to within 45 feet of the surface. It is soft, good water and flows enough to supply fifty cattle. This well is wholly in the drift. There is first, 8 feet of sand, then 90 feet of clay, then 5 feet of gravel in which the water is found.

WINOOSKI. Until 1905 this village in the town of Colchester was supplied with water from springs which were owned by a corporation. The water was collected in two reservoirs, but was not sufficient for the increased need of the large village. In 1905 the village bought the property of the Aqueduct Company and in addition set about improving it and increasing the supply. Two 8-inch wells were drilled and the water from these, raised by compressed air, is taken to the reservoirs and with that from three springs furnishes ample quantity for all ordinary uses. One of these wells is 412 feet deep, the other 453 feet. This latter was 206 feet in drift and 147 feet in rock. The other was 199 feet in drift and 213 in rock. In both, water was reached at about 100 feet. The Commissioners report as to the quantity given by the wells, "From the best tests we have been enabled to make, we feel warranted in saying that these wells would furnish at least 75 gallons per minute each for ten or twelve hours per day. This amount added to the natural flow of the springs will give abundance for present demands. As to the quality of the water we believe there is general satisfaction. The greatest problem has not been solved; viz: power (for pumping). So far the power used has been electricity. For convenience and giving little trouble it cannot be excelled. But there may be something cheaper; and if so we mean to have it. From the figures of the Aqueduct Co. the committee represented that, after paying running expenses and interest on bonds, there would be a gain of $1,500 a year, but as near as we can figure the ordinary running expenses for the eight months, the profit would be at the rate of over $2,000 per year."

At the large woolen mill near the Winooski river there is a well 495 feet deep. The natural flow is twenty-one gallons a minute, but when helped by a hot air engine it flows thirty-seven gallons. This well is almost wholly in the red sandstone, on a few feet of drift being gone through at the top. F. E. Thompson has a well 161 feet deep which gives fifty gallons a minute of soft water. The water is 50 feet deep in the well and is pumped. In the village of Winooski there are some ordinary wells, but the common supply is from the public system.

ESSEX. This town includes two villages, Essex Center and the larger one Essex Junction. Of the latter Mr. W. C. Sawyer writes—"Nearly everyone in town owned a well until the village water system was established in 1901. Since that time the use of wells has been abandoned in many cases. The village water comes from three large springs on the sandy plains between Essex Center and Williston." The water is piped to an open reservoir of 600,000 gallons capacity situated sixty feet above the village. As for ESSEX CENTER it may be said that both wells and springs are used, the latter where they are available as everyone prefers springs to wells since the spring water is invaribly softer and purer. There are some very good springs in the town.

HINESBURG. This town uses both wells and springs. There are some deep wells. Mr. H. W. Watson has one 198 feet deep in which water rises to within forty-two feet of the surface. The water is hard.

HUNTINGTON. This town is in part located on the western slope of the Green Mountains and springs abound and yet many families are reported as using common dug wells 12-20 feet deep.

JERICHO. Springs are common here but wells are also in use. At that part of the town known as JERICHO CORNERS, there is a small public system owned by Anson Field. About twenty families are supplied from this. The water is taken from Brown's River and forced into a tower from which it is distributed by gravity.

At JERICHO CENTER a supply owned by E. C. Bicknell is taken from two springs and distributed to perhaps a dozen families. Most of the residents, however, use either springs or wells on their own premises.

MILTON. Of this town Mr. D. D. Field reports, "Most of the families here in the village are supplied with spring water brought from the bank running north and south through the village. Said bank is full of water. What is termed the

Plain south of the village is supplied with water from wells 10-20 feet deep."

The well water in this region is reported hard. Some of the spring water is also hard, but most is soft as is the case everywhere in the State. In all parts of the town, springs are common, yet many wells are used.

RICHMOND. This town has a public system owned by a company. The water is taken from springs located in hills two miles from the village. There are some wells, but not many are reported as in use.

The water for the public supply is piped from the springs to a collecting reservoir and thence directly to houses. The water is somewhat hard, but not very, averaging about 80. There is one deep well owned by the Vermont Condensed Milk Company. This is 392 feet deep. It goes through 70 feet of clay and the rest is in rock. The water is hard. It rises to within 20 feet of the surface and is abundant.

SHELBURNE. As is the case in all the lake towns, those farms which are conveniently located get most or all of their water directly from the lake. Usually some sort of a windmill pump is used though occasionally a steam pump is used. Dr. W. S. Webb has his own water system in which the lake water is obtained from an intake which extends 2,200 feet out from shore and the water is raised by a steam pump to a reservoir which is 220 feet above the level of the lake and from here it is distributed over the estate. Several years ago a deep well was started on this place only 300 feet from the shore of the lake but after sinking it 1,400 feet in the shale and finding nothing it was abandoned. In this case as in some other deep wells in the Utica shale, water had to be supplied for the drill. Mr. C. E. Miner has a well on his farm in this town which is 268 feet deep. The water comes up to twenty feet below the surface This well is mainly in limestone, but the first 88 feet were through clay.

ST. GEORGE. This is a very small town containing but few families who are supplied from springs, or common shallow wells.

SOUTH BURLINTON. Is south and east of Burlington. In this town there are some springs, some ordinary shallow wells and some deep wells. In the eastern part of South Burlington the underlying rock is a more or less siliceous limestone, and some of the deep wells go into this. Mr. H. B. Chittenden has on his farm a well 185 feet deep which is mostly in the limestone. The first 35 feet are in drift, the rest in stone. No water of any account was found in drilling until a depth of 170 feet was reached and when the entire depth was reached the water rose to within 15 feet of the surface and by the use of a pump five gallons a minute are obtained. The ordinary wells here are from 20 to 40 feet deep.

UNDERHILL. This town extends up on the west side of Mt. Mansfield and as would be expected, springs abound everywhere. The rock is all crystalline or schistose and none of it soluble so that nearly all water is pure and good. Wells are not wholly wanting, but are rare. There is a public system owned by a company which furnishes spring water from a small reservoir to which it is piped from the springs. The water is soft and good. See anaylsis in table.

WESTFORD. This, like the preceding, is a town well furnished with springs. The report says "Small springs without number." And of course, from these the families are abundantly supplied.

WILLISTON. There are numerous springs in this town, but there are also many wells and some deep wells.

WINOOSKI. See under Colchester.

ESSEX COUNTY.

This county occupies the northeastern part of the State. Much of its area is only sparsely inhabited and there are no large towns. The surface is rugged, the rocks mostly metamorphic and therefore insoluble. Most of the county is well supplied with springs which afford an abundance of pure water. The county is bordered on its eastern side by the Connecticut River. It is also watered by several streams and contains many ponds, some of them of considerable size. It is forty-five miles long from north to south and twenty-three miles wide from east to west. There are nineteen townships in the county. Wells are few and there do not appear to be any deep wells. There are mineral springs, at two localities, Newark which has a sulphur spring and Brunswick where there are six in a group.

BLOOMFIELD. This town is largely supplied by springs.

BRIGHTON. The principal village in this township is *Island Pond,* which has a public supply coming mostly from springs, though two dug wells and a number of driven wells are reported. Nearly all families, however, get water from a system owned by the Island Pond Water Company. The springs from which the water is taken are on a mountain two miles from the village and two hundred feet above it giving a pressure of 90 pounds. There is a mineral spring in the town owned by Almon Smith. The water contains iron, magnesia and sulphur. It issues from slaty rock.

BRUNSWICK. All the farms in this town are reported to be supplied with spring water. The mineral springs have been already mentioned. They "Are all large flowing springs." The water of each is somewhat different from that in the rest, but all contain iron and sulphur.

CANAAN. This town has a public supply from springs which are situated across the line in Canada. The water is piped to a covered reservoir holding 22,000 gallons. See table for analysis. There are also some driven wells in the town.

CONCORD. "Very few wells in this vicinity. Water supply from running springs." Some of these springs are quite large. Cold spring supplies nearly twenty families, others eight or less, i. e. three or four and many one or two. Mr. C. S. Hastings writes of one of the Concord springs. "This is one of three

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springs within thirty rods of each other. Some years ago the water was run through a five inch sluice and at times the water was two inches deep. One of the other springs is quite large and with the overflow of a third furnishes water for the railroad tank at the North Concord depot. This third spring has an inch and a quarter pipe running to a tub on the highway. The overflow pipe from this tub takes water to the railroad tank and many times in the spring the water overflows the curbing which is four feet high. There is very little difference at different seasons in the flow of this spring and its temperature varies little from 47° F. in mid-summer or winter."

EAST HAVEN. This town is supplied by springs mainly, but there are a few rather shallow wells.

GRANBY. There is according to report, only one well in this town. All are supplied by springs. At Stevens' Mills in the north part of Granby there are more wells, usually about fourteen feet deep.

GUILDHALL. There are here no wells, but abundant springs. There is a public supply from springs just over the State line in New Hampshire.

LEMINGTON. There are here few wells. "Nearly every farm is supplied with spring water."

LUNENBURG. "Nearly everyone in town owns a spring large or small." There is a public supply from three large springs, the water of which is piped to the village.

MAIDSTONE. There are more wells in this town than in most parts of the county, these being the chief source of supply, though there are some springs.

NEWARK. Springs alone are reported from this town.

VICTORY. "Very hilly and rocky. The hills have abundance of good springs."

FRANKLIN COUNTY.

This is one of the counties lying along the Canadian border and on the west it is bordered by Lake Champlain. The eastern side includes a portion of the Green Mountains. Hence there is much diversity in the surface features of the county. Along the lake the land is often level, though even here hills are by no means wholly absent.

The eastern part is very rugged and uneven. Springs are everywhere abundant and wells are not numerous anywhere. In area this county embraces about six hundred square miles. It is about twenty-five miles from north to south and something over thirty from east to west. There are but few ponds. The northern part and the Lamoille runs through a portion of the southern border. These rivers with their tributaries water considerable portions of the county.

There are fifteen towns in the county. At least five of these are furnished by public supplies.

BAKERSFIELD. The Bakersfield Aqueduct Company supply water to this village of six hundred residents. Only one well is reported as used in the place and this only for cattle. Outside Mississquoi River crosses in a somewhat sinuous course the the village "Every farm has its spring." The public supply is taken from springs.

BERKSHIRE. Springs furnish most of the water used for domestic purposes in this town, but there are a few wells.

ENOSBURG. The town at large appears to be supplied with water for domestic use, from springs most commonly, though a few wells are used. Enosburg Falls, which is the principal part of the town so far as population and business goes, has two systems. One pumps the water from the Mississquoi River and carries it without any sort of purification to the various houses of its patrons. As a matter of course, this is liable at any time to contamination and is always open to suspicion. The other system is owned by the B. J. Kendall Company and takes its water from springs situated in the town of Berkshire. This latter supply is good soft water.

FAIRFAX. The water used for domestic purposes here is largely from wells though there are many springs. Ordinary wells are common, but there are a number of deep wells. Mr. W. H. Shepardson has a well with 8 inch tube which is 130 feet deep. Of the total depth, 80 feet are through drift and 50 feet in rock. It gives 2 gallons a minute. At the Bellows Academy there is another 8 inch well which is 425 feet deep. This goes through clay and gravel for 70 feet and 355 feet is in rock. It gives 2 gallons a minute. Another deep well in Fairfax is at the Creamery. This is 117 feet deep. The first 20 feet are sand and gravel, then comes a slate rock for the remainder of the depth. It has about the same capacity as that of the two preceding.

FAIRFIELD. There is a public supply here from springs and also numerous private springs on farms.

FLETCHER. "There are no wells here." "I know of no one who has a well, all are supplied with spring water." Another correspondent, however, reports some wells. These are 18-40 feet deep and give rather hard water. Springs are mostly used for the supply of drinking water.

FRANKLIN. There is a public supply owned by J. & W. S. Webster. This comes from a large spring. The water is soft. One correspondent writes—"Nearly every farmer in this section has springs and running water to house and barn."

GEORGIA. In this town, so far as can be ascertained from reports, which have come mostly from the western part of the township, the water from wells is mainly used. Springs are also used and the railroad tanks at East Georgia are supplied by springs.

HIGHGATE. Both springs and wells are in use here. There are several sulphur springs. As limestone abounds in this region all water is more or less hard. In the western part of Highgate, known as Highgate springs, are some springs that for many years have been used medicinally and the hotel near them has been a popular summer resort. The water shows the following parts in 1,000,000.

Sodium chloride	402.
Sodium sulphate	42.
Sodium carbonate	235.
Calcium carbonate	24.
Magnesia carbonate	10.
Potash and boracic acid	trace.

MONTGOMERY. Although "There are any amount of springs on all the farms," yet wells are considerably used in this place. On the average they are 20 feet deep and the water is hard. The wells appear to be mostly in the village while the farms outside are supplied with running water from springs. At MONTGOMERY CENTER there is a small public supply the water being taken from a brook. This water is piped to a reservoir 175 feet above the village.

RICHFORD. There is here a public system owned by the village. The water is taken from mountain springs and piped to an open reservoir which has a capacity of 70,000 gallons. It is high enough above the village to give a pressure of 142 pounds. See table for analysis. There are a few wells in use.

ST. ALBANS. There is a public supply here the water being taken from "Surface water shed of twelve hundred acres connected in two reservoirs, one built from a pond with a capacity of one hundred million gallons and the other, or new reservoir, having a capacity of one hundred and fifty million gallons." Analysis see table. These reservoirs are in Fairfax. In the city itself there is a reservoir which is five hundred feet above Lake Champlain and gives a pressure of three hundred pounds in the lower part of town. There is one deep well at the Franklin County Creamery. This is 177 feet in depth. It goes through 10 feet of drift, then in the Utica shale. The water rises fifteen feet above the top of the well and flows about three thousand gallons per hour.

Another deep well is on the property of the C. V. R. R. This is 350 feet deep. The bore is 8 inches. The first 50 feet are through gravel, then Utica shale. The flow is 30 gallons per minute.

SHELDON. Mr. J. T. Shepley of Sheldon Springs writes—"We use drinking water from a spring on the highway from St. Albans. We also pump water from the Mississquoi at our works and after being filtered it is taken to tenements." There is here a large mineral spring. The Mississquoi spring. The water of this is not only used at the spring, but bottled and shipped. The spring flows three hundred gallons daily. This water contains an unusual variety of materials as the following analysis shows.

Analysis of Mississquoi Spring water.

Total solids	224.8	Loss on ignition	39.4
Fixed solids	185.4		
Sodium chloride	.38	Calcium chloride	2.12
Magnesium chloride	.60	Sodium sulphate	6.52
Calcium sulphate	12.00	Aluminum sulphate	2.70
Magnesium sulphate	5.51	Sodium phosphate	0.08
Sodium bicarbonate	19.16	Potassium bicarbonate	4.11
Calcium bicarbonate	126.62	Magnesium bicarbonate	72.19
Manganous bicarbonate	1.40	Ferrous bicarbonate	3.03
Silicic acid	15.25	Crenic and Apocrenic acids	trace
Titanic acid	trace	Ammonia	0.08

SWANTON. The public supply is owned by the village. The water comes from the Mississquoi River and there is no filtration. There is no reservoir. By the pumps an ordinary pressure of forty pounds is obtained but this can be doubled if necessary. The water is soft and better than would be expected from such a source, but it must always be liable to serious contamination.

Outside of the village springs are used some of which give hard and some soft water.

GRAND ISLE COUNTY.

This county has a peculiar topography as it is composed of three islands and a peninsula in Lake Champlain. Its total area is given as only eighty-two square miles and it includes but five small towns. Naturally, the surface is much less irregular than that of any other part of the State and it possesses no elevation that is more than two hundred and eighty feet above the lake and very few are as high as this, most of the surface being only a few feet above the water of the lake. The rock underlying the surface soil is all either limestone or shale, more commonly the Utica shale.

From the character of this region it follows that many farms are located near the lake and can readily get water by windmill pumps and this method is commonly used. Wells are also common on farms which are too far from the shore to take lake water. Most of these are ordinary comparatively shallow wells, but there are a number of deep wells as will be seen from the following reports. In some parts of Grand Isle it has been found most satisfactory to dig very large, but not very deep wells. Some of these are 15-25 feet in diameter and 12-20 feet deep. Where the drift is deep, the wells are wholly in this deposit, but usually they go into the shale of limestone. In most cases the well water is very hard.. Springs would not be expected in such a region and yet there are quite a number. Cisterns are used by a number of the residents.

ALBURG. The rock in this town is wholly shale and there are several deep wells that have been drilled in this rock. The water is always hard and not infrequently contains sulphur and iron in small quantity. The deepest well is that of the Rutland R. R. near the station. This is 303 feet deep. The first 36 feet are in drift, the rest is in the shale. Water rises to within two or three feet of the surface. There is a flow of sixty gallons per minute. Other drilled wells are from 20-140 feet deep.

At ALBURG SPRINGS there are mineral waters which are used by many. Like the water at Highgate Springs, this is charged with sulphuretted hydrogen. An analysis is as follows:

Water from Alburg Spring. Parts in one million.

Sodium chloride	140.	Sodium sulphate	24.
Sodium carbonate	230.	Calcium carbonate	36.
Magnesia carbonate	22.	Potash and Boracic acid	traces.

ISLE LA MOTTE. There are very few springs on this island and almost everyone has a shallow well. All of them, so far as I could ascertain by inquiry, go through the drift at least to the top of the limestone ledge below, but not usually into it. The usual depth is not more than 15 to at most 20 feet. As in all limestone regions, the water is hard. The island is underlaid by Chazy and Trenton with a very small amount of Black River and a smaller area, along the extreme eastern edge, of Utica shale.

NORTH HERO. This peculiarly long, narrow and irregular body of land is wholly underlaid by Utica shale. There are a few springs which are used, but where water cannot conveniently be obtained from the lake, wells are the source of supply. These are ordinary shallow wells except one at the creamery where the shale has been entered to a depth of 120 feet and a good flow of water obtained.

GRAND ISLE. This town occupies the northern part of the island of the same name. The northern half, approximately, is Utica shale, but the southern part is largely Trenton, with patches of Chazy and Black River and, on the east Utica. The Trenton has been elevated so that it forms quite a ridge which in places is eighty or a hundred feet above the lake level. Most of the springs on the Island are in this ridge. But the main supply from which water is taken, aside from the lake, is the common and deep wells. At the creamery at Pearl, a post office in the town, several springs are used. The water flows into a small reservoir and from here it is pumped to the building where it is used for creamery purposes.

SOUTH HERO. This town includes the southern half of the island. The western part is mostly Trenton with patches of Chazy, Black River and a little Beekmantown. The eastern part is all of it Utica. The Trenton ridge mentioned above is continued through this part of the Island and in it are some few springs, but the water supply is much the same as in the northern portion of the Island. Some of the wells here as elsewhere in the county, are dry in summer, but many are always useful. The large wells mentioned previously are more constant than the smaller ones unless these latter are deep. For instance, on the Buel Landon farm there is a well sixteen feet in diameter and fourteen feet deep which has watered fifty cattle through the driest season. This well goes to the limestone and in this a shallow basin was blasted out. On the Dubuc farm is a well, bored, forty-two feet deep and this is never dry. Near the Iodine Spring House there is a spring which is charged with sulphuretted hydrogen and the water is reputed to contain iodine among other things, but I cannot get any analysis.

LAMOILLE COUNTY.

This county has the same varied topography that is found in most parts of this State. Along the Lamoille River which runs through the county from east to west there is level intervale land while away from this there are hills and mountains. A part of the Green Mountain range, including the northern end of Mansfield, the highest of the Green Mountains are in this county. Because of its hilly character the region abounds in springs and the brooks that come from them. There are also numerous ponds, especially in the eastern part of the county.

The rocks of Lamoille county are mostly crystalline metamorphic and therefore insoluble in water. The county is twenty seven miles in length from north to south and about the same in width and contains about four hundred square miles. There are ten towns included in the county. Several of these have public supplies of water and most are able to get sufficient spring water for their needs.

BELVIDERE. "Most of the water supply of this town is from springs which are generally considered good." There is little possibility of contamination in this sparsely settled region. There are a few wells in this town.

CAMBRIDGE. There is a village supply which comes from springs in that part of Cambridge which is in the village of JEFFERSONVILLE and here so far as I could learn there are no wells in use. In Cambridge proper, there are a few driven wells but nearly every family is supplied with spring water. There are a few common shallow wells. There is also in this part of the town a small public supply from springs. In that part of Cambridge called PLEASANT VALLEY there appears to be more wells in use than elsewhere. All the water is soft and good.

EDEN. While both wells and springs are used in this town the residents say that springs are far more frequently used. What wells there are end in the drift, the water being found in gravel. They are from 12-50 feet deep, water being found at from 10-16 feet.

ELMORE. Springs are mainly the source of supply here, though there are some wells. Families in East Elmore are supplied with water from a large spring owned by C. S. Budgett.

HYDE PARK. This is one of the most important towns of the county. The main village is provided with its water by a public supply which takes water from springs in the neighborhood, owned by Hon. C. S. Page. This supplies the larger part of the village, but there are other smaller supplies. In the Page system, the water of two large springs is pumped into a reservoir whence it is piped over the town. Outside of the village the water comes from springs and a few wells.

JOHNSON. There are several systems in this town, but most of the residents take water from that owned by the town. This takes water from a mountain brook fed by near springs so that it is practically spring water. For quality see table of analysis.

The water is taken from the brook to the village and what is not needed for ordinary uses is carried to a reservoir where it is stored to be used for fire purposes. There are a few wells in town.

MORRISVILLE. There is here a system owned by the village which like the preceding, takes the water of a mountain brook and springs, from which the water is piped to covered reservoirs and thence to the village. See analysis in table.

MORRISTOWN. This is the township of which Morrisville is the most important part. Outside of the village, wells appear to be largely used.

STOWE. A large spring furnishes a small public supply here. The village owns the system. For quality see table. Those not using this water for the most part use their own springs, but a few use wells.

WATERVILLE. Springs and wells are both used, but mostly springs. There are three small public systems from which many get water.

WOLCOTT. Springs are most commonly used in this place, but some wells are also used. The water usually comes from rock.

ORANGE COUNTY.

This county includes in its western portion a part of the Green Mountain range and is therefore rough and irregular and full of springs. The eastern portion, however, is less rugged and indeed, the most mountainous part is confined to the western border, the more level, or rather less uneven part covering more of the area of the county than the rougher part. The county is thirty-four miles from east to west and twenty-eight wide from north to south, and contains six hundred and fifty square miles.

On the east is the Connecticut River and several smaller streams flow through different parts of its area. The principal of these are the Wells, Waits, Ompompanoosuc, a branch of the Winooski and two branches of the White River. There are but few ponds. The most extensive rock is the Washington limestone. The Bradford schist is also quite extensive and there are granite deposits and slaty beds. These beds according to Dr. Richardson, are mainly Lower Trenton. The county contains seventeen towns.

For a full account of the geology of this county see Third Report pp. 61-101. These beds according to Dr. Richardson, are mainly lower Trenton. The county contains seventeen towns.

BRADFORD. Bradford village is supplied by a public system concerning which Mr. E. M. Everett writes "The water supply is derived from a series of springs forming two brooks which join and the water is piped to a reservoir near the village and high enough, two hundred and fifty feet, to give a pressure of one hundred pounds. This supplies a large part of the people with water for domestic use and other purposes. For analysis see table. In addition to this public supply, there are many families, especially those outside of the village, which have their own supply from springs or wells, mainly the former as wells are not numerous.

BRAINTREE. Driven wells are common in this town, although some springs are in use. In some if not in most of the driven wells the water apparently comes from an adjacent stream, a branch of the White River. Still the wells are not all alike as in some the water is soft, while it is hard in others.

BROOKFIELD. Mr. J. W. Parmenter writes: "The water supply here is almost entirely from small springs furnishing water to single farms. There is hardly a well in use in this locality. There are no large springs that would be sufficient for a water system." Mr. Alden Boyce writes of East Brookfield: "There is scarcely a farm in this town but has one or more springs on it. Therefore most of the people have running water from springs."

CHELSEA. This town has no public supply, the people getting their household water from wells and springs, the former being most commonly used. Cisterns are also used to some extent, because the well water is quite hard, so that for laundry purposes it cannot well be used.

CORINTH. "The surface of this town is broken into hill and valley, therefore farmers largely have abandoned the ordinary wells of the earlier inhabitants and bring water for house and barn from the spring which issues from the hillside. These springs are mostly small. But there is one, the Darling Spring which has the dimension of a small brook issuing from a cleft in a ledge at the foot of a hill." C. T. SARGENT.

Wells are also used by a not inconsiderable number of residents.

Mr. C. L. Speare writes of Corinth and West Corinth: "There are very few springs in this section. Nearly all wells are what I call drainage wells, that is, wells into which the water filters from the top of a sort of hardpan which is stuck in this section from three to ten feet, but at Corinth Center the wells are from 25 to 40 feet deep and a few considerably deeper, one being 96 feet deep. All are dug and stoned up, no driven wells nearer than Chelsea and none bored. I have dug quite a number and simply dig till we get water enough and are tired of digging in the hard pan. I have never dug through it and do not know its depth. At Corinth and Corinth Center there is quicksand."

FAIRLEE. There are in this town springs, dug wells and driven wells. Mr. C. F. Thourber writes: "The main water supply is brought from a brook. There are not many wells in town." Mr. G. W. Comstock writes of West Fairlee: "There are no wells or pumps used in this part of town. Our water is furnished by flowing springs."

NEWBURY. Water is obtained here from both wells and springs. The relative number of these varies in different parts of the town. Mr. N. B. Tewksbury writes of Newbury Center: "There are very few wells in this part of town and those that there are the people use only in warm weather." Mr. J. B. Tyler says of West Newbury: "The people here are mostly supplied by springs."

ORANGE. In this town "but few people get their supply from wells. As far as I know most get water from springs that come out on top of the ground. There are some large springs that boil up out of the ground and that seldom dry up in a drouth, but the smaller springs often dry up in a dry time." Mr. E. G. PEAKE

RANDOLPH. There are in the various parts of this town South Randolph, Randolph Center, East Randolph, many small springs and some of considerable volume. Some are constant, both in flow and temperature.

In the village of Randolph there is a public supply which takes the water of twenty springs located two miles and a half from the village. The water is filtered and distributed from a million gallon reservoir situated two hundred and forty feet above the town, giving a pressure of a hundred and five pounds. Analysis see table. The water is ordinarily taken not from the reservoir, but directly from the springs, the reservoir being kept up mainly for fire purposes. The water is somewhat hard, 85, but is considered good. There are some wells in town which vary from 8-20 feet in depth.

STRAFFORD. Springs appear to be almost the only supply in this town as "Springs are found on every farm."

SOUTH STRAFFORD. About the same conditions exist here as in Strafford, that is, spring water is mostly used, but there are a few wells.

THETFORD. Both springs and wells are used here and, so far as can be discovered from the reports received, in about equal numbers. Still Mr. W. S. Combs writes: "The water supply is mostly from wells, the water of which is pumped, though there are a few springs which are used for family supply." The water of the wells is hard. Water can usually be found by digging 10-20 feet below the surface.

In that part of Thetford called *Post Mills*, there is a spring strongly impregnated with iron.

In NORTH THETFORD there are two small public systems owned by the Union Water Company and The North Thetford Water Company. They supply twelve or fifteen families each. There are a few drilled wells in the town.

TOPSHAM. Ordinarily, springs are used in this town, but there are some wells. These latter are quite shallow.

TUNBRIDGE. Both in Tunbridge and South Tunbridge there is a plentiful supply of good spring water coming from numerous small springs. Very few wells are in use and there are no deep wells.

VERSHIRE. The drinking water here is mostly obtained from wells which average about 15 feet in depth. The water is considered soft.

WASHINGTON. Both springs and wells are used in this town. There are about as many of one as of the other. There is also one private system in town. This is owned by G. E. Huntington and water is taken from a large spring to 15-20 families.

WELLS RIVER. This village is a part of the town of Newbury and might well have been considered under that town, but it is usually regarded as a place by itself and therefore it is so treated here. There is a public supply furnished with water pumped from Wells River into a reservoir two hundred and twenty feet above the town. The river water is filtered and distributed through the village. There are a few wells reported and numerous springs.

WEST FAIRLEE. "Nearly every one here owns his own springs and has the best of water." E. P. GEORGE.

WILLIAMSTOWN. There are here abundant springs which supply the residents of this town with good water.

ORLEANS COUNTY.

The second county from the eastern border of the State in the northern tier along the Canada line is Orleans. It is thirty-three miles from north to south and thirty from east to west. It contains eighteen towns.

The surface is most of it very rugged and in parts mountainous. Perhaps no county in the state is more irregular in its surface features than this. The rocks are mostly metamorphic or granitic, and therefore do not materially affect the water. The larger streams are the Missisquoi, Barton, Black, Clyde, and Lamoille rivers. The county lies largely between the eastern and western ranges of the Green Mountains and many of the peaks and foot hills of these ranges are wholly within its limits. Beside the southern end of Memphremagog, which extends from Canada eight miles into Orleans county, there are numerous lakes and ponds, some of which are not inconsiderable in size, and are well known as popular resorts as Willoughby, Caspian, Seymour, Echo, etc. Twelve of the towns have within their borders ponds of a size sufficient to provide a water supply if it were needed. But no such supply is called for since the whole county, as would be expected from its topography, is amply furnished with springs which supply running water and purer than most ponds contain. As will be seen in the following reports, nearly all the towns in this county can get spring water. The well-nigh universal reply to inquiries as to the supply of water suitable for domestic purposes was, "Few wells and many springs in this town."

ALBANY. Water here is largely from springs, but there are a few wells though of no great depth. The water in both wells and springs varies, being hard in some cases and soft in others. Here as elsewhere, the well water is more often hard and the spring water soft. In digging wells water is most commonly found in a layer of sand. There is a public supply owned by the Albany Water Company which takes water from a group of springs.

BARTON. Almost the only source of drinking water here is springs. Some of the best springs flow out of granite rock and the water is regarded as very fine. It is soft, cold and pure. A correspondent writes that he knows of only three wells in town. There is a village supply which uses the water of a mountain brook. The water is filtered and stored in a reservoir holding a million gallons. It is high enough to give a pressure of a hundred and fifty pounds. BARTON LANDING also has a public supply which comes from springs and is piped to a reservoir holding thirty thousand gallons. There is here a pressure of forty pounds.

BROWNINGTON. This town is supplied by springs and wells in apparently about equal number. Mr. C. A. H. Gardyne writes: "Brownington as a whole is principally an upland plateau with a number of flat cedar swamps of from twenty to a hundred acres. There are no large streams flowing through the town, but it is well watered by small brooks. On some of the higher ridges there are not many springs, but generally spring water can be had for farm buildings. This water is generally soft. Water in wells is found at from 10 to 20 feet and is good but hard, and forms lime scales in kettles. The springs are mostly rather small. The valley of the Willoughby River abounds in fine surface springs, but the location of many prevents their utilization."

CHARLESTON. This is a long, narrow township with a village at each end known as East and West Charleston. Springs abound in both. In WEST CHARLESTON there are a number of wells, though the greater number of families use spring water. In EAST CHARLESTON, only one well is reported. There are several ponds in this town and the Clyde River runs through Pension Pond to Salem Pond in Derby and on through this into Memphremagog.

COVENTRY. Most families in this town are reported as getting their water supply from springs. Yet wells do not appear to be uncommon. Much of the water is hard.

CRAFTSBURY. Here the conditions seem to be much like the preceding, wells and springs furnishing the water. Most families, however, being able to get spring water.

DERBY. This is one of the border towns. The rock is largely granite. There is a public supply owned by H. S. Haskell. The water used in this comes from a number of springs the water from them being carried to three reservoirs and thence distributed. This water is described as "medium soft." Wells, some of them quite deep, are used by a number of families Some of these are fifty, sixty and seventy-five feet deep. Some go through the drift into the underlying rock. In that part of the town known as DERBY LINE there is a public supply from springs.

GLOVER. In this town hills and valleys abound and some parts are very rugged. There are four good-sized ponds and numerous streams. The drinking water mostly comes from springs. Mr. Chapin Leonard writes: "The water supply of this town is mostly furnished by individual springs with gravity delivery. Few people are obliged to use wells." Mr. G. A. Dow of WEST GLOVER writes: "Water is very limey in wells and the spring water is rather hard. The depth of wells is given as from 6 to 12 feet. Those wells that go into the rock are regarded as better and more abundant in water than those that end in drift." Mr. Lyman Barlow of West Glover writes: "There is one spring in EAST GLOVER that supplies nine families and another that if put to use would be sufficient to supply quite a village. There are a number of springs in this section that would supply several families if utilized. Almost every house is furnished with a spring of its own."

GREENSBORO. This is also a hilly region though less so than many parts of the county, and there is considerable woodland. Caspian Lake, Elligo Pond, Long Pond and other smaller bodies of water are in this town. Wells are common and water is pumped by windmills from some of the ponds. Springs are also common and are much used.

HOLLAND. Springs appear to be the main source of water supply here.

IRASBURG. Water in this town is obtained from wells, springs, and in some cases, cisterns. Springs, it is said, furnish most of the water used for domestic purposes. This water is usually soft.

JAY. This is a mountainous town and springs abound, but wells are somewhat used. The water from the springs is reported soft and clear.

LOWELL. This town is nearly surrounded by mountains and from these abundant spring water flows. Still there are some wells from 20 to 30 feet deep. The water in different wells appears to vary in quality. For example Mr. G. W. Crafts says: "We have two wells about six rods distant and the water in one is soft and in the other hard. Each is twenty-five feet deep."

MORGAN. This town is reported as having springs everywhere and very few wells.

NEWPORT. There are two public supplies in Newport. The Newport Water Company, owned by the village, takes water from Derby Pond a mile east of Derby Center. The water flows from the pond to a reservoir holding a million gallons. The water is hard. For analysis see table. The other system, owned by the Raymond Water Company, takes its supply from a spring and the water is piped to a covered reservoir holding a hundred thousand gallons.

TROY. This village and also NORTH TROY are supplied by public systems taking water from a mountain stream in one case and from springs in the other. The water is said to be soft and pure.

WESTFIELD. Nearly every farm here has its own springs from which running water is piped to buildings.

WESTMORE. "A great many fine springs of the best of water." "There are no wells in this vicinity."

RUTLAND COUNTY.

In area, population and number of towns, Rutland County is the largest in the State. It is forty two miles from north to south and thirty-four miles from east to west. It contains nine hundred and fifty-eight square miles.

The principal stream is Otter Creek which flows through the length of the county and there are several smaller streams flowing through different parts of the area. There is considerable level land in the valley of the Otter and much beautiful scenery. Outside of the valley of the Otter, the surface is much broken and in the eastern part, mountainous.

Some of the higher summits of the Green Mountain range as Pico, Killington, Shrewsbury, etc., are included in this county.

There are about a dozen lakes and ponds from some of which water is pumped. Some of the lakes as Bomoseen, St. Catherine, Hortonia are places of summer resort.

There are twenty-eight towns in the county, many of them of some importance.

The rocks of this region are quite diverse. In the eastern portion there are the usual schists, gneisses, etc. of the Green Mountain uplift. Through the middle portion there is the great marble belt from which most of this stone sent from the State is taken. This extends through Brandon, Pittsford, Proctor, Rutland, West Rutland, Clarendon, Wallingford and Danby, coming from Addison County on the north and going on a short distance into Bennington County on the south. West of the marble area, but not as extensive, is the slate belt which reaches from near Brandon to Fair Haven, Poultney, Pawlet, and Rupert, though not without some breaks.

Naturally, these various sorts of rocks affect the character of the water and in general the water supply.

BENSON. This is one of the two towns in Rutland County that has Lake Champlain on its western border, and like all lake towns, it gets all the water that it can conveniently directly from the lake.

The rock in this town is Ordovician limestone and shale and the character of the country is such as to preclude the abundance of springs found in so many parts of the State. The character of the rock makes all water hard and in some cases so much so as to be objectionable.

Where water cannot be taken from Lake Champlain it is generally taken from wells. These are many of them drilled into the underlying rock and vary in depth from fifty to a hundred and fifty feet.

In a few cases the water in these wells rises to the surface and even flows over, but it does not in any case rise much above the surface.

BRANDON. Water is obtained here from various sources, but the main supply, the town system, is brought from a pond called Fern Lake which is some six miles north of the main village and 165 feet above it so that water readily flows from the lake to the town. Fern Lake is fed by springs which bubble up in it and to some extent by brooks. The lake itself is the only reservoir. Its surroundings are said to be good, but the north end is marshy and there is complaint that in summer the water has a strong vegetable taste and odor.

About three hundred families are supplied with this water and some motors. For analysis see table.

Otter Creek flows through this town and its water is used to some extent. Probably this water is not much used for domestic purposes.

Analysis of Otter Creek water at this point is as follows:

Total solids.........95.20	Free ammonia 018
Loss on ignition.....32.00	Albuminoid Ammonia 184
Fixed solids 63.20	Chlorine 1.80
Hardness ....62.	

A few wells are still used in Brandon. The water is very hard.

At FORESTDALE, a small village in the east part of the town the water is mostly obtained from wells.

CASTLETON. Wells of various sorts, drilled, dug, driven, deep, shallow are in use in this town. Springs are also used. All the water is hard. Wells are more used than springs.

CENTER RUTLAND. There is a public supply in this village derived from a large spring which is owned by the Vermont Marble Company.

The spring is walled and covered and there is a small reservoir a hundred feet above the town. The water is soft and is considered good.

CHITTENDEN. Springs abound in this town and are universally used. A very few wells are also used. The springs are not only very abundant, but are reported as constant and never failing.

CLARENDON. "This place is in the valley of the Otter and the farms are located on each slope of the valley. Each farm has a supply of water from springs on higher slopes." A few wells are also in use. The Post Master of East Clarendon writes "There are no wells in my delivery. All water is obtained from springs."

Clarendon is somewhat of a resort on account of its mineral spring analysis of which was given in the last report. Mr. Robert Murray the manager of the hotel writes "The water is naturally carbonated, mildly aperient containing as the principal mineral ingredient lime and magnesia salts, which account for its alkaline character and to a great extent its medicinal properties. The Company controls four springs, three moderate size and one large. The large spring has a flow of twenty or thirty million gallons a year."

DANBY. Mr. E. J. Rood writes of this town: "With the mountains rising abruptly on two sides the majority of our inhabitants living in the Creek valley we are blessed with an abundance of springs, almost too many. At the present time (March 1905), the village is supplied with water from a single spring located two miles back on the mountain. There are a few families, however, who have not the town water but get it from wells in their cellar or near the house. One can dig down almost anywhere here and strike water which has more or less current."

FAIR HAVEN. There is a public supply here obtained from Inman Pond a body of water some three miles north of the town and a hundred and ninety feet higher. The pond is eighty acres in extent and surrounded by forest and pasture. The water is piped directly to the village with no reservoir. It is rather hard, but otherwise is good.

HUBBARDTON. Water from springs and wells is mostly used in this town, but that from streams and cisterns is also used to some extent. All water in this region appears to be soft, or at least not very hard. The northern part of Lake Bomoseen is in this town and water from this source is used by some. Mr. H. M. Redfield writes "Hubbardton is well watered by springs, streams, lake and ponds. The quality of the water varies. Springs within twenty rods of each other will often be one soft and the other hard. A portion of the soil is clay, a large portion slaty, a portion sandy loam. The surface is all hills and valleys." In HORTONVILLE which is in the town, there are some deep drilled wells from which water is pumped by windmill. This water is sometimes alkaline. Mr. D. P. Narramore writes, "I have a well that I dug several years ago. It is on nearly the highest ground between Lakes Hortonia and Hortonville. I should judge about seventy five feet above the Lake Hortonia and the land slopes all around the well and it has never failed to give all the water I needed." Mr. C. M. Morgan has a well on this same ridge and several feet higher.

IRA. There are many large springs in the hills of this town which never fail. Wells from eight to thirty feet deep are also somewhat used, but springs supply most of the water.

MENDON. It is said that there are no wells in this town, but that the numerous springs furnish ample water for all the needs of the residents. As will be seen later, the public supply of Rutland is taken from brooks in this town.

MIDDLETOWN SPRINGS. Wells are used here to some extent, but springs much more. The Montvert Springs Company have a fine hotel and mineral springs in the village. The water analysis of which is given below is recommended for "Rheumatism, gout, indigestion, etc."

Analysis of water used by Montvert Springs Company.

70,000 grains contain:

Lime	1.936	grains.
Iron protoxide	.829	"
Alumina	.084	"
Soda	1.997	"
Carbonic Acid	4.229	"
Magnesia	.602	"
Manganese	.726	"
Potash	1.997	"
Sulphuric Acid	.085	"
Chlorine	.705	"

The above substances are combined as follows:

Calcium Sulphate	.144	grains
Calcium Carbonate	3.351	"
Manganese	1.176	"
Potassium Chloride	1.304	"
Sodium Carbonate	3.218	"
Magnesium Carbonate	1.265	"
Iron	1.335	"
Alumina	.084	"
Sodium Chloride	.217	"

There are a few deep wells in the town which are drilled into the underlying rock.

MOUNT HOLLY. Here two springs supply most of the water used, but wells are also in use. Mr. E. D. Barr writes "Near Summit station there are two mineral springs that issue from the rocks. They are about a rod and a half apart. One tastes strongly of sulphur, the other is said to contain more iron."

In that part of Mount Holly known as Mechanicsville only springs are reported.

PAWLET. This town is largely underlaid by Ordovician and Cambrian rock, slates, shales, limestone and quartzite with some schist. The water supply is mostly from wells. These are of various sorts, ordinary dug, driven, and deep. Ordinary wells are from fifteen to thirty-five feet deep while the driven wells are deeper and the drilled wells are from one to six hundred feet or even more.

Mr. W. O. Williams writes of West Pawlet "Cistern water is used to a great extent but about sixty families are supplied from a well owned by J. McFadden."

PITTSFIELD. This town has a water system owned by C. W. Brigham & Co., which takes water from a stream. Wells, usually from 10-20 feet deep are used and also some springs.

PITTSFORD. The chief supply here is from what is known as "The Sand Spring". This is a very large spring four miles north of the village on a mountain side in the town of Chittenden. Mr. C. J. Fenton, Town Clerk writes: "This spring has been sounded to a depth of three hundred feet without finding bottom. A fair sized brook runs away from it, or did before it was utilized for our supply."

The spring is owned by the Pittsford Aqueduct Company and furnishes an unfailing supply to a hundred and twenty or more families.

Wells and cisterns are also somewhat in use. Of that part of Pittsford known as FLORENCE Mr. T. R. Willis writes as follows: "The wells and springs on the west side of Otter Creek are hard or lime water, while on the east side nearly all are soft water." This would be expected because the rocks about Florence are marble and limestone.

POULTNEY. This town is in the midst of the slate belt. There are deep wells, springs and cisterns in use, and in addition, the water of Poultney River and Lake St. Catherine is used and there is a public supply from Crystal Lake a body of water about two miles from the village and two hundred and seventy-five feet above it. Hence the town has no lack in this respect. For analysis of the public supply see table.

The common wells go down from 15-30 feet, water being usually found in a layer of sand and gravel, but a few enter the rock.

PROCTOR. There is a public supply here. Formerly the water was taken from springs, but within a few years the source has been changed to Coal Kiln Brook. The watershed from which this brook takes its supply is largely forest covered. The water is piped over seven miles to an iron stand pipe which holds three hundred and fifty gallons. The brook is in the town of Chittenden. The water is soft in the new supply, but was hard in that formerly used.

RUTLAND. The public supply comes from spring fed brooks in Mendon, four miles east of the city, on the slope of Killington.

About two thousand families are thus supplied. The quantity does not appear to be sufficient in a dry time as in the summer of 1904, the city was very seriously threatened with a water famine for some days. Moreover according to the report of the Board of Health. "The Watershed is not protected and streams are polluted in many cases by dwellings along their course."

The water from the brooks is first taken to two settling ponds and thence to a five million gallon reservoir. For analysis see table.

SHERBURNE. This is a mountain town and like all such places in this State is abundantly furnished with good springs. "All the water is soft and has considerable iron in it." Brook water is used by a few families. In this case such water is practically spring water.

SHREWSBURY. This is also a mountain town and very much the same conditions exist here as in Sherburne, all water used being from springs, which are found everywhere. I do not hear of any wells in either of these towns, except in that part of Shrewsbury called CUTTINGSVILLE where wells are to be found, though not numerous. What there are do not go far into the ground all being quite shallow.

SUDBURY. Here there is a different condition of rock and surface and wells are more common. The region is hilly, but not mountainous and nearer the lake. Both ordinary dug and some drilled wells are found. Nevertheless "Most of the farms use spring water."

TINMOUTH. Shallow wells are used here to some extent, but most commonly the water is from springs.

WALLINGFORD. Springs afford most of the water used for drinking in this town. "There are not over ten wells in the village." These are shallow. Mr. H. G. Savery writes: "The water supply of the village of Wallingford is almost entirely taken from springs which are never affected by high water or drought. The quantity is sufficient to supply ten times that used." Of SOUTH WALLINGFORD Mr. T. Thompson says: "Most of the water used in South Wallingford is furnished by the South Wallingford Water Supply Company. They take water from a spring that comes from an old ore mine."

WELLS. This is one of the towns in the slate belt, and the Ordovician beds underlying the town are similar to those at Pawlet and Poultney. Mr. O. R. Hopson writes: "There are no deep or artesian wells in this town. Our supply comes from ordinary dug or driven wells twelve to thirty feet deep. There are several fine flowing springs that come from the base of the mountain within half a mile of the village. The water of one of the springs is used for bottling."

WEST HAVEN. This town is situated on the lower part of Lake Champlain and on the south runs the Poultney River. Water is pumped from both of these sources. The lake is not a desirable source of supply here at it is narrow, shallow and muddy. Drinking water appears to be mostly obtained from deep wells. The underlying rock is Ordovician limestone and shale and hence the water is quite hard.

WEST RUTLAND. Until 1904 this town depended mainly upon wells, but since then a public system has been installed and from this most of the residents get their water.

The supply is obtained from a mountain brook which has been dammed as it flows through a deep ravine and in this way a large reservoir partly natural and partly artificial, has been made. This is over a mile from the village and considerably above it so that a pressure of a hundred and twenty five pounds is obtained in the central portion of the town. The water is found by analysis to be of good quality and abundant in quantity. There are no dwellings near the brook before it enters the reservoir from which it is piped.

It is said that in many of the wells in use before the public supply was provided there was a perceptible current in the water which was reached at depths of from 6-10 feet, though driven wells were sunk deeper in the hope of getting a larger and more constant supply.

The quality of the well water varied. In some it was soft and in others hard.

WASHINGTON COUNTY.

This county is bordered on the east and west by mountains and hills and mountains are scattered through its area. It is thirty-four miles from north to south and thirty-one from east to west. The Winooski River runs through it in a northwesterly direction and several of its principal branches are largely in this county as the Mad, Dog and other rivers and streams. There are numerous ponds in the northeastern portion, but few elsewhere. The rocks are largely limestone, (the Washington Limestone of Richardson see Third Report of Vermont Geologist) schists and granite. There are very extensive beds of this latter rock in the eastern part of the county. The geology of this county is taken up in detail in the Third Report in Dr. Richardson's article on The Terranes of Orange County, pp. 61-101, and also in the article by Mr. G. I. Finlay on The Granite Area of Barre, pp. 46-59. In both of the above articles there is much valuable information as to the rocks of portions of this county as well as of those of adjacent areas. Washington County includes twenty towns.

BARRE. This is the largest town in the county which has grown up very rapidly from a country village and has not yet become fully settled in its present status. It is not only supplied by a public water system, but has almost a superfluity of them. The country about Barre is hilly and the hills are steep and full of springs.

At present, there are six supplies from which several families take water and outside of the city numerous farms have each its spring or springs. The main supply, that controlled by the city, comes from several brooks; Orange Brook, Scott Brook, Williamstown Brook, Barre Brook, and Martin Brook. The principal source, however, is Orange Brook, Barre Brook coming next in importance. A correspondent writes: "The two main sources of water in Barre are Orange Brook and Bolster Reservoir, the former coming from the town of Orange with an unpolluted watershed of about ten square miles. This has a temporary open reservoir which holds twenty million gallons. The latter supply has a water shed of about ten square miles and includes Peck Pond. It has an open storage reservoir which can hold twenty-three million gallons." For analysis of this water see table. About twelve hundred families are supplied by the municipal system. There is pressure at the office of the Superintendent of a hundred and thirty pounds. The system is a gravity one, but there is a pump which can be used if necessary.

Besides this large system there are, as has been mentioned, five others, some of these are small, reaching only a few families, others are larger. Mr. H. R. Worthen has a spring which supplies one business block and three families. The water is said to be good, but hard.

The Crystal Spring Company supply some two hundred and fifty families. This water is piped from a spring to a reservoir and thence distributed.

Mr. Harvey Hersey takes water from six springs and supplies over forty families. The springs come out from schist and the water is soft. The Barre Spring and Fountain Company supply a number of families taking water from springs.

The Barre Pure Spring Water Company supply a hundred and seventy-five families and could furnish a larger number. The water is taken from a large spring to a reservoir whence it is distributed.

At Graniteville, Messrs. E. L. Smith & Company have a well a hundred and fifty feet deep in the granite. The water rises to within a few feet from the surface. It is rather hard and contains some iron. Elsewhere in this village, as springs do not occur, wells are used by all inhabitants.

BERLIN. Families in this village have wells, but the farms outside of the village are for the most part supplied with springs from which they take water.

CABOT. This town is supplied from numerous ordinary wells.

CALAIS. Wells ten to thirty feet deep are largely used here. In EAST CALAIS, however, springs are used and the familiar report is again repeated." "Every farm has its own supply of spring water." There are a few shallow wells and as in many towns, these afford the main supply in the village while the springs are used outside of it. So too in that part of Calais called SODOM springs are mainly used, though some families use both springs and wells. Mr. A. A. Bliss writes, "This part of the country being very hilly gives a good chance for springs to burst out of the hillsides, usually near the north or south end of a ledge," the ledges running nearly north, east and southwest. In the wells water is reached within twenty feet.

DUXBURY. This is a mountain town lying at the base of *Camel's Hump*. From this it follows that the surface is very hilly and springs are abundant. Still there are some wells used.

EAST MONTPELIER. This village is supplied mainly by springs.

FAYSTON. This town is almost wholly supplied from springs, there being only a few and shallow wells. The water is soft and good.

MARSHFIELD. There is a village supply here taking water from mountain springs. The system is owned by the Betchelder Water Works Company. The collected water of the springs is piped to small reservoirs and from these to the village. The water is soft and pure.

Outside of the village each family has its own supply of spring water. Though there are a few wells in use.

MIDDLESEX. Spring water is universally used here. There are three systems from which the village is supplied. The water in both is very soft. Mr. M. W. Miles has a large spring which supplies seventeen families. The water is pure and good. For analysis of this water see table.

Messrs. Shepard and Hobart have four springs and supply eight families, and Mrs. C. C. Ainsworth has three springs from which eleven families take water. These sources are all on the south side of the Winooski River which flows through the town and the water is piped across.

MONTPELIER. This town has probably a greater number of more or less public water supplies than any of which I have any knowledge in this or any other State. There is first and by far the most largely used the city system which supplies about eight hundred families, besides shops, stone sheds, etc. This water is piped from Berlin Pond nearly four miles and a half from town and four hundred and thirty feet above the main streets. The watershed is large, about fifteen thousand acres it is reported, but is not well protected. From the pond the water flows through an open passage to a reservoir of six millions of gallons capacity. This water is not always satisfactory and various efforts have been made to remedy sources of contamination and with some measure of success, still the water is not above suspicion.

Besides this more general supply there are at least fourteen others.

Montpelier is largely built in a rather narrow and deep valley and naturally, springs abound in the surrounding hills. The rock is mainly schist. Yet with all its sources of supply this place has time and again been threatened with lack of water in very dry seasons.

Of the various smaller systems the following are the principal ones. The Hubbard system takes water from a group of thirteen springs which are connected so that they can be used in groups, a part being used as long as sufficient and when needed others can be added. Over two hundred families are supplied with this water which is rather hard.

The Corry Spring in East Montpelier is piped to the city and supplies some twenty families.

The Shurtleff Spring supplies nine families. The water is harder than most obtained in the region.

The Blanchard Spring is a large and constant supply for over twenty families and three large business blocks. The water is softer than that of many of the springs in this locality and is considered very good. The spring is located on a hillside and two hundred and seventy-five feet above the river.

The Graham Spring is small and is used by only a single family.

A spring on the Dewey estate supplies the Pavillion hotel and one family. It is located in the north part of town.

The Swinton Spring supplies twelve families. The water is hard. The Mather Spring supplies three families and is large enough to supply more as much of the water runs away.

The Brook's Spring supplies four families and has been in use for over fifty years. The water is soft.

The Smilie Spring supplies sixteen families. The water is moderately hard.

The Hinckley Spring on Seminary Hill supplies twenty families and a large boarding house which has often two hundred occupants. The water is considered wholesome, but hard.

The Langdon Spring supplies several stores, a large restaurant and a number of families. It is a large spring and its flow has been found to be a thousand gallons an hour. It is in East Montpelier and is piped into the city. The water is perhaps the best and softest of any of the springs enumerated.

The Colby Spring, formerly used has been condemned and is not used. There are several other springs from which water is taken in different parts of Montpelier, but they are of less importance than those mentioned. In North Montpelier the water used is spring water.

MORETOWN. Mr. L. Wilcox reports, "There are no wells in this town that I can recall. Families are furnished with water from small springs. Usually each family has its own spring."

NORTHFIELD. This village is supplied by two Companies. The Northfield Aqueduct Company take water from four springs and a brook a mile and a quarter from the town and five hundred feet above it. There is no reservoir but the water is piped directly. The water is very soft and otherwise good. The Andrews Aqueduct Company take their water from springs on hills east of town about a mile and a half distant and a thousand feet above it. There is no reservoir. The water is harder than that of the other Company, though not very hard.

PLAINFIELD. This town is almost wholly supplied by springs, but there are a few wells, from 10-50 feet deep. The water is soft but in some cases has a sulphurous taste. Mr. J. S. Chamberlain writes: "There is seldom a farmhouse that cannot be supplied with good spring water running to it though some are short during a long drought. The supply of Plainfield village comes from the base of a sand hill with no buildings nearer than half a mile. If all the water of this spring were used it would supply a village of fifteen hundred inhabitants, but at present the village has but four hundred and fifty residents."

ROXBURY. This town while using spring water mostly has been also in part supplied from wells. These are from 10-20 feet deep. Very few, if any of the wells are now used. There is a town system which supplies many families. The water comes from springs. The water is good and soft. Outside of the village each farm has its own spring.

WAITSFIELD. "The water supply comes from numerous springs on the hillside."

WARREN. Water here is mostly from springs though there are some few wells. The water is soft. The wells are from 8-15 feet deep.

WATERBURY. There are several systems in this village. That owned by the town takes water from a group of springs in Stowe seven miles distant. There is here a small covered storage reservoir and from this the water is piped to Waterbury and distributed directly to houses, but the surplus is taken to a reservoir two hundred feet higher than the village and is used ordinarily only for fire purposes. The water is soft and pure.

What is known as The Hopkins, Somerville and Warren system supplies about sixty families in Waterbury center and there are two or three smaller systems. A few wells are also used.

WOODBURY. Water here is mainly taken from Springs, though there are a few wells in use.

WORCESTER. Springs are most used here as sources of water, each family having its own. Wells are also used to some extent.

WINDHAM COUNTY.

This county forms the southeastern part of the State. It is thirty-six miles from north to south and twenty-eight from east to west. It contains seven hundred and eighty square miles and there is in it twenty-three towns.

The Connecticut River flows along its eastern border while Williams, Saxtons, West and Deerfield rivers water different parts of its area. The surface is hilly and irregular with some mountainous towns in the western part. The rocks are probably for the most part Precambrian, though some of the masses are a little later.

ATHENS. The water supply in this town is wholly from springs.

BELLOWS FALLS. This is in the town of Rockingham, but it is so much more widely known by the village name that it is treated as if an independent town. The chief water supply here is that owned by the town which takes water from Minards Pond which is about one and a quarter miles from the village. Farr Brook is used as supplementary to the pond. The system flows by gravity and affords a pressure of a hundred and fifteen pounds. Mr. A. Cooledge writes that he does not know that any wells are used for domestic purposes. The water is very soft.

BRATTLEBORO. The principal supply in this town is that furnished by the Chestnut Hill Reservoir Company. The water used by this company is taken from springs and collected in a six million gallon reservoir whence it is piped over the village. The water is very soft and otherwise good. Another supply is the Western Aqueduct Company. This company uses spring water collected in a covered reservoir. The water is harder than that from Chestnut Hill and does not appear to analyze as well in other respects. Besides these larger supplies, there are numerous small supplies from small springs the water from which is said to be "very excellent."

In time of need the water of West River is pumped and used.

BROOKLINE. Mr. C. P. Stickney writes of this place: "In this locality the hillsides abound in cool springs which furnish most of the water for domestic use." There are also a number of wells in the village, some of which have water with mineral matter. There is a mineral spring from which at different times considerable water has been bottled and shipped from the Railroad Station at Newfane. The water is said to have "A great local reputation for its medicinal qualities."

DOVER. Spring water is universally used here but in East Dover, wells are used especially in hot weather when the spring water is in some cases too warm to be palatable by the time it reaches the house through pipes.

DUMMERSTON. Springs coming from seams in the rocks or bubbling from the ground furnish the most common supply. Wells are also used to some extent. Some of these are deep.

GRAFTON. Springs and ordinary wells supply this town.

GUILFORD. "Most of the water used for domestic purposes comes from springs." H. Stowe.

HALIFAX. Although wells are used in this town, springs are more commonly the source of the water supply.

JAMAICA. Mr. J. C. Robinson writes, "Jamaica is a rough, hilly town with many good living springs on the hill sides and at their bases. A large number of these springs supply water for family use and for cattle in the pastures. The water is clear, soft and apparently pure. Most springs have a larger flow in the spring of the year. The water is cooler in some than in others. There are about twenty families in Jamaica village supplied by fifteen springs."

LONDONDERRY. Wells and springs appear to be used about equally in this place. The wells are usually shallow and the water is not very satisfactory. That from springs is considered good.

MARLBORO. "Upon most of the farms here there is an ordinary well, but very few are used at the present time, running water from springs having taken the place of well water." Mr. A. W. Prouty.

NEWFANE. Springs are mostly used in this town. Wells, however, are used to some extent. There is no public supply. Mr. M. O. Howe writes, "There is comparatively no clay in Newfane or in most of the towns in Windham county, but at a depth of a few feet, the gravel is very hard and compact usually and surface water can easily be excluded. Surface springs frequently flow from fissures in rock."

Mineral spring water is shipped from this place, but as noticed in the proper place, the spring is in Brookline.

PUTNEY. Springs and wells are both used. The latter are reported as from 12-20 feet deep.

ROCKINGHAM. The principal part of this town known as Bellows Falls has already been considered. The town outside of Bellows Falls is abundantly supplied by springs.

SOMERSET. Water is wholly from springs which are good and abundant.

STRATTON. This is a mountain town at least in part and ample water can be obtained by most of the residents from springs. Still some wells are used.

TOWNSHEND. Wells and springs are apparently used in about equal numbers. The water of both is soft, or in wells not very hard. The wells as usual in this region are not deep.

VERNON. Here as in the previously named town are wells and springs. There are some deep wells.

WARDSBORO. "The water for family use is from wells dug and stoned up. They vary in depth from 10-20 or 30 feet. Others obtain their supply from springs on hillsides and conduct it to their houses in pipes. In some localities these springs are numerous and as a rule, are to be found at the foot of land sloping to the north. I know of one boiling spring close beside a brook on level ground that never fails and the water comes up through quicksand which by the action of the water has made a mound of earth in shape like a sugar loaf and the grass is green all the year. I also know of a spring on a side hill sloping to the northwest that comes up through a round hole in the solid ledge. The hole is an inch and a quarter in diameter and the water always fills it and there appears to be a good deal of pressure behind." H. E. KIDDER.

WESTMINSTER. Mr. G. H. Walker says: "We have no deep wells in this town. There is a large spring that supplies the village for the most part. There are a few small wells 20-30 feet deep." At Westminster station there are a few driven wells.

WHITINGHAM. "There are no artesian or deep wells here. All around on the hillsides are springs and our wells are only a few feet deep. The water is very fine." A. A. BUTTERFIELD.

WILMINGTON. "Our domestic water supply is entirely from springs or from shallow wells fed by springs." O. H. Jones.

WINDHAM. "There are no large springs in this place. As most every house is supplied by private springs." A. W. CHAPMAN.

"The water supply of this town is mostly living springs. We have beautiful, soft spring water never failing among these hills." S. M. SMITH.

WINDSOR COUNTY.

This is one of the counties which is bordered by the Connecticut River. It is forty-eight miles from north to south and thirty miles from east to west. Besides the Connecticut River on the east there are the White in the northern part, the Quechee in the central part, the Black in the southern part. The county contains nine hundred square miles. The prevailing rocks are slates, schists, and some granite in the southern part. There is also a considerable development of the Waits River limestone, Bradford schist and some other rocks.

The county includes twenty-four towns.

As a whole this county is less mountainous than most of those in the State, but the northeastern towns are very much upheaved and irregular and there are more or less isolated mountain masses elsewhere.

ANDOVER. Both wells and springs are used in this town, probably the latter more commonly. As far as I have been able to ascertain, in Andover proper wells are most in use while in that part called SIMONSVILLE springs are more common.

BALTIMORE. Mr. W. R. Bryant writes of this town, "Our town lies at the foot of Hawk Mountain and our people are supplied with drinking water from springs flowing from the side of the mountain." Some wells are also reported in this town.

BARNARD. Wells appear to be the main source of supply in this town. Still a few springs are reported.

BETHEL. There is here no public supply, but groups of families in some cases get their water from a common source, which is a large spring. Most of the people, however, get water from private springs. There are very few wells in use. "This village is situated in the White River valley and the hills on either side are full of springs which does away with all necessity for wells." M. W. Arnold. As examples of the small supplies mentioned above there may be named the following: C. D. Cushman supplies the families at "The Corners" from a large spring. J. A. Graham supplies families on River Street; E. D. Gilson supplies North Main Street, and so on.

At EAST BETHEL there are more wells, but still most families use springs.

BRIDGEWATER. This is one of the most mountainous towns in this county and as would be expected, "Nearly every family is supplied with spring water." In Bridgewater village there are a few wells, but in WEST BRIDGEWATER none are reported, only springs.

At BRIDGEWATER CORNERS both springs and wells are used though wells are less common. The water of both wells and springs is reported as soft.

CAVENDISH. Springs are largely used here, but there are also both driven and dug wells. Some of these wells are very excellent and furnish a large supply of water. For instance Mr. C. E. Warfield says that "A few years ago seven families had all their water from my well." In that part of Cavendish called PROCTORSVILLE only wells are reported.

CHESTER. Mr. G. L. Fletcher writes from this town, "Springs are plenty, pure and good. Wells are first class. There are more than four hundred wells dug and stoned. Until fifteen years ago running water was scarce, but latterly, persons who had used wells have brought water in pipes from springs to their houses and we have a water company that bring water in an iron pipe from a reservoir which receives the water of a small brook two thirds of a mile from the South Village and those who had no spring water have taken that furnished by the Company. Three rivers run through Chester, North Branch, South Branch, Middle Branch of Williams River and many wells are fed by under currents from these streams, as is shown by the fact that in digging the wells water is reached at the level of that in the streams. The Middle Branch runs through the main part of the town, Chester Village, while North Branch runs through North Chester and Chester Depot and the three unite about a mile east of Chester Station."

Mr. F. W. Pierce says of his own well, "This well in common with others in the main part of Chester Village is dug in what is evidently an old river bed. The writer, as well as most of his neighbors, depends for water for drinking upon that brought by the Water Company."

This Company takes the water of a brook which has a watershed of between three and four hundred acres much of which is owned by the Company. They have an open reservoir holding five hundred thousand gallons. It is about two miles and a half from the main village.

For analysis see table, page 257

HARTFORD. There are several water companies in this place and in that part of the town known as White River Junction all taking water from springs. There are also many private springs in use particularly outside of the villages which supply single families. The water of Cæsar Brook is piped to Hartford and supplies about forty families. This water is soft and pure.

Mr. H. C. Pease writes, "Two years ago I bought four acres of land, one acre being swamp from which clear cold water always runs. I laid deep in the gravel six hundred feet of tile pipe and conducted the water to a reservoir. This spring is the largest in town and flows twenty thousand gallons daily." Twenty or more families are supplied with this water. White River Junction will be considered in order.

HARTLAND. Hartland is not well supplied with springs and must therefore depend upon wells. Still there are a few springs.

LUDLOW. This village has a public system; as to this Mr. W. M. Bixby writes, "Within the village limits very little water is used except that from the public system. This is taken from mountain springs, elevation about six hundred feet. At present we take about half the flow which never varies." Outside the village springs are used, and also some wells.

NORWICH. This village has a public supply owned by the Norwich Aqueduct Company. The water comes from springs. Wells which are fifteen to twenty feet deep are also in use. Wells are more commonly used outside of the village. The water in both wells and springs is reported hard. In a part of the town called Lewiston there is a driven well sixty-five feet deep in which the water rises thirty-three feet. Mr. C. P. Brown writes that, "This well goes below the bed of the river (Connecticut) and there seems to be an endless supply of water. We have run the pumps even seven or eight hours at a time and could see no difference in the supply of water."

Shallower driven wells are common near the river which flows along the eastern border.

PLYMOUTH. Springs supply most of the water used in this town. Some of the springs are reported to be quite large.

POMFRET. Springs on all the hills and mountains about this town.

READING. The water used in this town is reported to be from wells and to be soft. Some of the wells are only four or five feet deep and are practically springs. Other wells are deeper down to twenty-five feet.

ROCHESTER. There is in this village a public system owned by the town. The water is taken from springs, ten in all, and collected in two small reservoirs and then it is piped to a large open reservoir built of stone and cement and holding over a hundred and five thousand gallons. There is a pressure in the village of ninety-six pounds. The water is soft and pure.

ROYALTON. The water used in this village is supplied from ordinary springs and wells. In SOUTH ROYALTON, springs are almost the only source of supply.

SHARON. Both springs and wells are used. Springs mostly. Wells are from ten to twenty feet deep.

SPRINGFIELD. There is no public supply, but abundant springs supply the households. Some wells are reported, but springs are the principal source of supply. The well water is not regarded as good as the spring water.

STOCKBRIDGE. "All of the people here receive their water from springs." G. B. Fish.

Of GAYSVILLE, a village in this town, Mr. F. P. Baker writes, "The water supply is obtained from small springs in the hills except occasionally a well in the valley which well is usually deep enough to be on a level with the river."

WEATHERSFIELD. Water is obtained to some extent from wells, but more commonly from springs. As usual, the wells give hard water while the springs give soft. The wells are shallow. Some of the spring water from the hills is reported hard.

WESTON. Springs are mainly used, but there are also wells.

WEST WINDSOR. Springs and wells are used. Springs most commonly and the water from them is most satisfactory.

WHITE RIVER JUNCTION. Although this place is a part of the town of Hartford, it is so well known by its local name that it is treated as an independent town. There are here several water supplies taking water from springs. There is a supply owned by the village which furnishes water to more families than any other system. About two hundred and fifty families get their supply from this source. The water is taken from brooks which are fed by springs. The water is collected in large reservoirs from which it flows over the village A large spring located about a mile south of the village owned by Mrs. E. J. Wallace supplies about a hundred families. Mr. G. W. Smith has used on his premises water from White River filtered.

This is rather hard, but is otherwise considered good. Mr. Smith also had a well drilled to a depth of two hundred feet but the water was not pure and no use was made of it. The Hartford Water Company also supplied families in this part of the town.

WILDER. This is another village in Hartford. It has its own water supply owned by the Olcott Water Company. The water is taken from three springs, two of which give soft water and one hard. The water is distributed by hydraulic rams and aqueduct and about fifteen thousand gallons are supplied daily. It is reported that there are "No wells in this vicinity." Outside of the village the farms have small springs which supply them.

WINDSOR. This town has a public system which takes water from springs, and supplies most of the town. The water is collected and pumped to a stand pipe. Water from Dudley Brook is also used, but mostly for motors, though formerly it was used for domestic purposes.

WOODSTOCK. There is a public supply here taken from a stream. The water is rather hard, but is reported as very satisfactory, except as to supply. Mr. George Aitken writes, "We have running through the town a nice brook which will furnish plenty of water, but in order to get sufficient fall for power and fire purposes, will necessitate the building of about four miles of large piping and the damming of the stream, this is now being talked about, and I have no doubt will be done during the next two or three years at least.

We have several large, fine springs near by, these are a source of revenue to the owners during the summer months, being distributed through the village in five and ten gallon carboys at a moderate price.

Our public water is very fine, and perfectly satisfactory, only lack of quantity."

WEST WOODSTOCK. "The people here use the aqueduct water principally. This comes from living springs."

SOUTH WOODSTOCK. There are numerous springs here and also many wells. Some of the springs are large.

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